# UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1166

Washington, D. C. July 26, 1923

# APPLE BY-PRODUCTS AS STOCK FOODS

By

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Miscellaneous Division, Bureau of Chemistry

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1923

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# APPLE BY-PRODUCTS AS STOCK FOODS.

By G. P. WALTON, *Assistant Chemist*, and G. L. BIDWELL, *Chemist in Charge, Cattle Food Laboratory, Miscellaneous Division, Bureau of Chemistry.*[1]

## PURPOSE OF INVESTIGATION.

Shortly after the close of the World War American manufacturers became greatly interested in the possibilities of utilizing dried apple pomace and similar dried residues as stock foods. Information, founded on scientific research, concerning the feeding value of dried apple by-products and their effect on the production of milk when fed to cows was limited. Accordingly, the Bureau of Chemistry of the United States Department of Agriculture undertook an investigation of the utilization as stock food of dried apple pomace and dried apple-pectin pulp. Special attention was given to the value of the dried pomace and pectin pulp as sources of succulence for cows during the winter.

## UTILIZATION OF APPLE BY-PRODUCTS.

The first industrial problem in connection with the by-products of the apple probably arose with the first crude attempts to prepare a drink from its juice. Evidently the early cider makers (*1–6*)[2] were not greatly impressed with the value of cider press cake, or apple pomace, as food for stock, in spite of the fact that Cato and Varro (*77*) and other Roman writers on agricultural subjects had advocated the feeding of grape marc, the refuse from wine making. The use of apple pomace as a food for stock may have been ignored for the reason that, according to Evelyn (*1*) and Mortimer (*4*), the fruit employed for making cider at that time was so harsh that swine refused to eat it even before the juice had been extracted.

In 1708 Philips (*120*), the first to mention in the literature the possibility of feeding apple residues to animals, recommended the final press cake from cider making as a fertilizer. By the end of

[1] The feeding trials with dried apple pomace and dried apple-pectin pulp reported in this bulletin were conducted at the Beltsville Experiment Farm, Bureau of Animal Industry, Dairy Division, T. E. Woodward, Dairy Husbandman, in charge.

[2] The italic numbers in parentheses throughout this bulletin refer to the literature cited, pages 35 to 39.

the eighteenth century some consideration had been given to the utilization of apple pomace. Marshall (*112*) states that the offal, or "dry must," had but little value as manure, but was used as fuel at times and also as feed for pigs.

Since that time the advantage of utilizing press residues as a feed is never lost to sight. Before 1800 in Normandy and Brittany measures seem to have been taken to preserve apple pomace when it was abundant for use in feeding stock during the winter (*121*).

Many years later Storer (*130*) suggested ensiling apple pomace, "a process of preservation which is largely employed in Europe for keeping soft and juicy material." Later it developed that 30 years before Storer's publication had been issued a Massachusetts farmer had preserved apple pomace by storing it in a pit under his barn and had fed it to his cows during the winter.

It is generally accepted that apple pomace has a very low value as fertilizer. According to Browne (*53*), it is worth nearly as much for fuel as it is for fertilizer. Warcollier (*138*) states that it is worth six times as much for stock food as it is for fertilizer.

Only a small part of the total pomace produced can be profitably used in the fresh condition because of its perishable nature when moist. It may be ensiled, yielding a succulent cattle food comparable to corn silage, of real value in the winter feeding of cows; but the quantity that can be thus utilized is limited by the prohibitive cost of transporting material of such high water content more than a few miles from the source of supply.

The ultimate solution, then, of the problem of utilizing the great bulk of apple pomace lies in its preservation by dehydration. In the form of dried pomace it may be stored for a long time and used as desired in the manufacture of pectin, evaporated apple products, vinegar, or stock for "apple-base jelly." Because of the low water content of this material when properly dried, it may be shipped at a comparatively low cost.

Apple pomace was first dried in the United States by a few manufacturers on a small scale for jam and jelly purposes in 1915.[3] Eight years earlier a Canadian cider manufacturer had undertaken the preparation of dried apple pomace as a commercial stock food. While not possessing high quality as a feed, this product was sweet and attractive to cows and sheep. It contained only 8.5 per cent of moisture, but had a very low crude protein and fat content.

Vernon (*135*) and Warcollier (*138*) state that the drying of cider residues has long been practiced in Germany, particularly at certain cities on the upper Rhine. At Frankfort an association (La Pomosin) specialized in the commercial drying of the wet pomace from that region. The dried pomace ordinarily was not used for stock food, however, but was sold to manufacturers of jellies and preserves. In 1911, because of a shortage of material in Germany, negotiations were opened with French cider makers for a supply of dried pomace. This started the industry on a commercial scale in France.

The new enterprise did not make rapid headway at first, owing to the uncertainty as to whether the German demand would persist longer than the shortage of German pomace. By 1918, however,

[3] According to S. L. Crawford, an industrial chemist.

Warcollier and Hédiard state that the more important French cider mills were equipped for drying the marc which they produced and that obtainable from the farms. As a matter of fact, the French have practiced the air drying of marcs for many years. "Nouveau Cours Complet d'Agriculture" (*67*) describes the cutting of the press cakes into 1-foot squares and drying in tiers for use as fuel. Houzeau (*87*) and Cornevin (*61*) advised drying in the same manner for fuel or for the winter feeding of rabbits. Probably this also was the method referred to by Storer (*130*) when, in discussing means of preserving pomace, he mentions "the ordinary method of drying."

In England apple pomace was dried before 1910. In 1911 several tons of cider residues were dried in a kiln used for drying brewers' grains and fed to cattle (*39*). From an incomplete chemical analysis the material appears to have been of average composition, and the animals did well on the dried "chads" in mixtures with other feeds. The quantity drying of pomace had been developed during 1909 or 1910.

This by-product industry evidently made progress in England, for when the French war mission to study cider making in England visited the British Isles in 1916, the larger mills had a well-established trade in dried pomace (*139*). A cider mill in Devonshire was equipped to dry $5\frac{1}{2}$ tons of fresh marc to a water content of 12 per cent every 12 hours. The dried pomace was sold to American importers for $13.60 a ton (normal exchange). English farmers bought it for from $8.80 to $13.25 a ton.

In the United States the publications of Lewis and Brown, of the Oregon Agricultural Experiment Station (*98*), and of Caldwell, of the Washington station (*56*, *58*), advocating the salvaging of waste fruit products by desiccation, deserve some of the credit for starting the movement for the commercial production of dried apple pomace.

The preparation of jellies, jams, and similar fruit confections requires the presence of a sufficient quantity of pectin to insure a firm, properly jellied product. Crude pectin is readily obtainable from certain fruits, notably the apple, and in recent years apple pectin in a concentrated and more or less purified form has become of some importance as a trade commodity. Apple pectin in constantly increasing quantities, either in the crude state or after concentration, is being used. The pulp left after the pectin has been extracted offers possibilities as a feeding stuff, particularly in plants where evaporators for drying pectin pulp press cake have been installed.

## YIELD OF APPLE BY-PRODUCTS.

From the standpoint of the practical cider maker, an apple consists of but two parts, juice and marc, or solids not in solution (*104*). If the soluble constituents are completely extracted, only about 4 per cent of solids remains. In other words, the total juice, including water and soluble constituents, is about 96 per cent of the apple. This percentage, of course, varies somewhat with the type of fruit. Table 1 gives the composition of various parts of the apple as reported in the literature.

TABLE 1.—*Analyses of portions of the apple (reported in the literature).*

| Product. | Moisture. | Ether extract. | Crude fiber. | Crude protein. | Ash. | Nitrogen-free extract. | Reducing sugars as invert. | Sucrose. | Total sugars. | Degree of acidity. | Pectin. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Composition on original basis. | | | | | | | | | | |
| | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *Cc. N acid per kilo.* | *P. ct.* |
| Whole apple: | | | | | | | | | | | |
| Pennsylvania [1] | 80.9 | | | 0.4 | 0.3 | | 9.9 | 2.2 | 12.1 | 61 | |
| Canada [2] | 82.7 | | 3.0 | .5 | | | | | [3] 11.0 | | 2.0 |
| Edible flesh: [4] | | | | | | | | | | | |
| Baldwin | 84.1 | 0.3 | .9 | .2 | .2 | 14.3 | | | | | |
| Russet | 82.2 | .5 | 1.0 | .3 | .3 | 15.7 | | | | | |
| Skins: [4] | | | | | | | | | | | |
| Baldwin | 71.6 | 2.3 | 5.4 | 1.0 | .4 | 19.3 | | | | | |
| Russet | 70.0 | 1.7 | 5.0 | 1.1 | .5 | 21.7 | | | | | |

| Product. | Moisture. | Ether extract. | Crude fiber. | Crude protein. | Ash. | Nitrogen-free extract. | Reducing sugars as invert. | Sucrose. | Total sugars as invert. | Pectin. | Pentosans. | Galactans. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Composition on moisture-free basis. | | | | | | | | | | |
| | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| Whole apple: | | | | | | | | | | | | |
| Pennsylvania [1] | 80.9 | | | 2.3 | 1.7 | | 51.6 | 11.3 | 62.9 | | | |
| Canada [2] | 82.7 | | 17.3 | 2.9 | | | | | 63.6 | 11.6 | | |
| Edible flesh: [4] | | | | | | | | | | | | |
| Baldwin | 84.1 | | | | | | | | | | | |
| Russet | 82.2 | | | | | | | | | | | |
| Average | | 2.4 | 5.4 | 1.8 | 1.2 | 89.2 | | | | | | |
| Skins: [4] | | | | | | | | | | | | |
| Baldwin | 71.6 | | | | | | | | | | | |
| Russet | 70.0 | | | | | | | | | | | |
| Average | | 6.8 | 17.8 | 3.8 | 1.4 | 70.2 | | | | | | |
| Seeds: | | | | | | | | | | | | |
| Whole, fresh [5] | 37–39 | 18.6 | 18.5 | 33.1 | 3.7 | 26.1 | | | | | | |
| Kernels [6] | 6.5 | 32.7 | 1.5 | 48.0 | 4.8 | 13.0 | .2 | | 3.3 | | 2.5 | |
| Seed hulls [6] | 10.6 | 9.0 | 22.0 | 8.6 | 2.1 | 58.3 | 1.9 | | 3.7 | | 13.4 | |
| Entire [6] | 8.0 | 24.1 | 9.0 | 33.6 | 3.8 | 29.5 | .8 | | 3.4 | | 6.7 | |
| Average entire (2) | | 21.3 | 13.8 | 33.4 | 3.7 | 27.8 | | | | | | |
| Marc [7] | | .7 | 30.9 | 3.4 | 1.0 | 64.0 | 1.7 | | | | {24.5 / [8] 15.5} | [8] 13.0 |

[1] Reported by Browne (*53*).
[2] Reported by Meunier (*114*).
[3] As invert sugar.
[4] Reported by Storer (*130*).
[5] Reported by Lloyd (*103*).
[6] Reported by Huber (*88*). The air-dry seed consisted of 62.5 per cent kernels and 37.5 per cent hulls; the moisture-free seeds consisted of 63.5 per cent kernels and 36.5 per cent hulls.
[7] Insoluble in cold water. Results reported by Bigelow and Gore (*45*).
[8] Extracted by boiling water.

When apples are pressed in a modern cider mill the yield of juice ordinarily does not exceed 80 per cent of the quantity originally present in the fruit. Thus the solid residue, known as apple pomace, is about 23 per cent of the weight of the apples crushed. According to Barker (*39*), the grater type of mill makes it possible to press out a very high proportion of juice, occasionally as much as 90 per cent of the weight of the fruit. Cruess (*62*) states that a ton of apples

should yield 160 gallons of juice (33 per cent of pomace) if well pressed. He recommends a pressure of not less than 500 pounds per square inch. The pressure commonly recommended for factory practice for the larger modern cider presses is 300 pounds per square inch of "cheese."

Reports from a large number of cider mills in the United States show that the yield of pomace is about 30 per cent, on the average, based on a water content of 80 per cent.[4] In American mills the pomace dry matter constitutes about 6 per cent of the weight of the apples crushed. These, of course, are only rough estimates. The proportion of pomace produced depends upon the quality of the fruit and the type of mill.

The estimates of the total tonnage of apple pomace produced by commercial operators in an average year is based on reports from cider manufacturers. It is assumed that 15,000,000 48-pound bushels of apples are pressed for cider each year[5] in the New England States, New York, New Jersey, Pennsylvania, Virginia, West Virginia, Ohio, and Michigan, and that 7,500,000 bushels are pressed in the rest of the country, making a total of 22,500,000 bushels. This would give 162,000 tons of pomace containing 80 per cent of moisture. In addition, many thousands of tons of pomace are produced on the farms. Fippin (*66*) states that 5,250,000 gallons of cider were made on New York farms in 1909, an increase of 1,000,000 gallons over the average yearly production for the preceding decade. This quantity of cider would result in the production of over 9,000 tons of moist pomace on the farms of New York alone.

## MANUFACTURE OF DRIED APPLE BY-PRODUCTS.

### APPLE POMACE.

In 1916 (*139*) one of the larger mills in England which dried apple pomace on the commercial scale used rotary dryers of German make, such as are employed for drying exhausted beet cosettes. The technique of drying apple pomace and similar products is discussed in most of the recent French papers reviewed. Those of Vernon (*135*), Warcollier (*138*, *139*), and Tanvez (*131*) include details of value. La Cidrerie (*131*) gives the following description of the operation of a Vernon rotary drying system.

Three units of varying capacity, capable of handling 770, 1,210, and 1,980 pounds, respectively, of fresh pomace per hour, are employed. Three workmen (an engineer, a man to feed the dryer, and one to sack and weigh the finished product) are needed. The three units require 4, 6, and 8 horsepower, respectively. From 40 to 50 pounds of coal is used in the production of each 100 pounds of dried pomace. On this basis the fuel cost in the United States per ton of dried pomace would be between $3 and $4. Rotary kilns seem to have been generally adopted.

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[4] The average moisture content of fresh apple pomace from 81 American determinations is 80 per cent; from 15 English determinations, 71.3 per cent; from 8 French determinations, 79.6 per cent; and from 5 German determinations, 75.2 per cent; an average of 78.6 per cent for 109 determinations. Many of the determinations included, however, were made before efficient presses were the rule. The average moisture content of American twice-pressed pomace probably is to-day almost 75 per cent.

[5] The pressing season in northeastern United States is from September to December, inclusive.

In the United States the steam-heated rotary dryer (Fig. 1) seems to be held in greatest favor, owing to the absence of danger from scorching the product. The pomace is run first through a picker and then through the rotating drum which is the real dryer. From the lower end of the drum the dried pomace is conveyed to the storage bin. The older slatted-floor kiln, commonly used in the evaporation of apples, is also employed in drying pomace.

A simple calculation serves to show that 1 ton of dried pomace with a moisture content of 10 per cent can be obtained from 4½ tons of wet pomace containing 80 per cent of moisture.[6]

In France it has long been the custom to recover the apple seeds, which are sold to orchardists and nurseries. Elutriation is some-

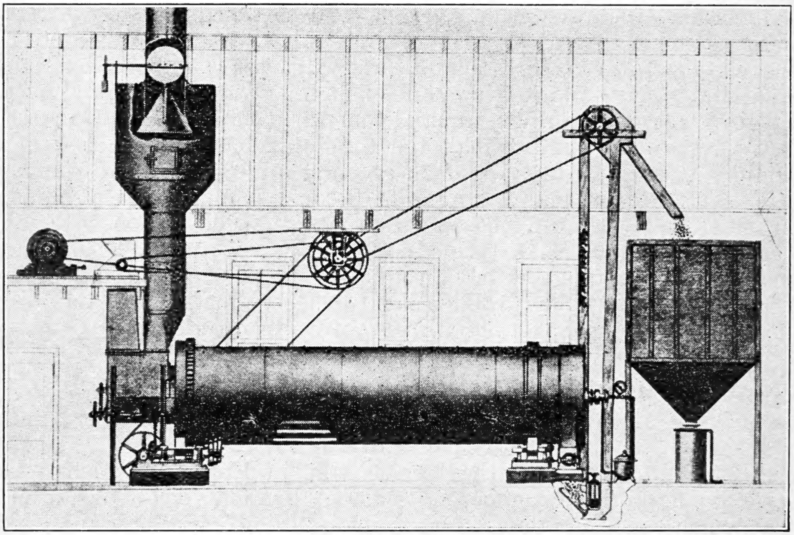

FIG. 1.—Steam-heated rotary pomace dryer.

times used for this purpose. This separation is also accomplished by shaking machines, fans, or winnowers which are put into operation after the water content of the pomace has been reduced to 25 per cent. Precautions must, of course, be taken not to impair the viability of the seeds by letting the temperature become too high.

The cost of drying pomace containing 65 to 70 per cent of water down to a moisture content of 12 to 13 per cent is given by Warcollier (*138*) as 3.5 francs per 100 kilos ($6.14 normal exchange per ton) of the dried material.[7] This agrees with a recent estimate on the cost of drying obtained from an American authority, who states that with a steam dryer of the rotary type, capable of handling between 21 and 24 tons of wet pomace in 24 hours, and a consequent output of from 5 to 7 tons of dried pomace, the cost of drying will

[6] Under present conditions of American factory practice, pomace which has been pressed a second time in the manufacture of vinegar stock contains from 74 to 78 per cent of moisture. This means that from 3½ to 4 tons of the press cake will yield 1 ton of the dried product.

[7] This refers to conditions in France just before the World War.

vary from \$5 to \$7 per ton of dried product. With a smaller machine, handling from 12 to 14 tons of the press cake per 24 hours, the cost of drying is increased to between \$6 and \$8 per ton of dried pomace produced.

In France, in 1918, the selling price of dried apple pomace was \$29 a ton (*140*). Manufacturers in the United States state that they receive for dried apple pomace, as it comes from the dryer without being ground, \$30 to \$50 a ton in carload lots, f. o. b. shipping point. The surplus dried pomace, however, could be bought in 1921 for feed for \$25 a ton, after the needs of manufacturers of pectin and related products had been satisfied. One manufacturer estimated the cost of handling and drying the pomace in 1921 at \$15 to \$20 a ton. In 1921 more than 50 tons of material billed as "apple waste," valued at between \$47.50 and \$50 a ton, entered the port of Boston. This material was shipped from Nova Scotia and probably was not apple pomace, but dried peels and cores. One manufacturer believes that dried pectin pulp can be made and sold in the unground condition for about \$25 a ton.

## APPLE-PECTIN PULP.

The apple products utilized on a commercial scale as a source of pectin are chops (apples, usually culls, which without peeling or removing the cores have been sliced and dried), dried cores and skins from canneries and drying-houses, known commercially as waste, and apple pomace (cider press cake), generally bought by pectin manufacturers in the dried state. The dried residuum, after extraction of such products with both cold and boiling water, offers possibilities as a stock food. This material is generally known as dried apple-pectin pulp.

At one of the large fruit-products factories the process of manufacturing pectin, and incidentally pectin pulp, is essentially as follows:

The chops, waste, or dried pomace, as the case may be, is first desugared by extraction with cold water and then cooked with boiling water or live steam until the pectin is brought into solution, after which the greater part of the pectin liquor is squeezed out of the mass in a hydraulic press.[8]

As it leaves the press the extracted press cake residue, variously termed "apple-pectin pulp" and "extracted apple pomace," is a moist product, containing from 75 to 85 per cent of water, by weight. Because of this high water content the extracted press cake is subject to rapid spoilage, which may account in part for the fact that when first called to the attention of the Bureau of Chemistry the material was a liability to the manufacturer of pectin.

Probably not less than 8,000 tons of the moist material, equivalent to more than 2,000 tons of dried pectin pulp, was produced in the United States during the 1920–21 season. This quantity would be increased many times should the feed show promise and a market for it be developed.

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[8] The expressed liquid containing the pectin is usually first clarified and then concentrated by evaporation, the degree of purification and concentration depending on whether the pectin is to be used immediately or is to be stored or prepared for the trade.

Thousands of tons of pomace are allowed to go to waste annually in the cider and vinegar industry at the present time. Once the manufacturers realize the importance of the sugar and other valuable carbohydrates that remain in the cider press cake, it is probable that a serious attempt will be made to salvage these substances by extraction, thereby increasing the production of pectin pulp.

So far as is known, only three of the several factories producing pectin are equipped for drying the pulp and supplying the dried product to the market as stock food. Other manufacturers produce pectin, and the recognition of the by-product as a stock food doubtless would result in the commercial drying of their pulp residues.

## COMPOSITION OF APPLE BY-PRODUCTS.

### APPLE POMACE AND APPLE-POMACE SILAGE.

Jacquemin and Alliot (*90*) report a study of the composition of first, second, and third pressing pomace made by Seguin and Pailheret. A summary of the analyses of apple pomace and apple-pomace silage found in the literature is given in Tables 2, 3, and 4, which also show the average analyses of repressed pomaces. Every effort has been made to avoid duplication in recording these analyses.

TABLE 2.—*Cattle-food analyses of apple pomace and apple-pomace silage (reported in the literature).*

| Product. | No. of analyses. | Composition on original basis. | | | | | | Composition on moisture-free basis.[1] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Moisture. | Ether extract. | Crude fiber. | Crude protein. | Ash. | Nitrogen-free extract. | Ether extract. | Crude fiber. | Crude protein. | Ash. | Nitrogen-free extract. |
| Fresh (moist) apple pomace: | | | | | | | | | | | | |
| American— | | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| Minimum | ...... | 69.9 | 0.7 | 2.0 | 0.7 | 0.2 | 7.9 | 2.0 | 8.8 | 3.9 | 1.1 | 54.8 |
| Maximum | ...... | 87.5 | 2.0 | 7.7 | 1.9 | 2.3 | 21.2 | 9.1 | 29.7 | 8.1 | 7.6 | 79.4 |
| Average | [2] 31 | 78.6 | 1.2 | 3.7 | 1.3 | .6 | 14.6 | 5.4 | 18.0 | 5.8 | 2.8 | 68.0 |
| English (average) | 8 | 71.7 | 1.2 | 6.7 | 1.3 | 2.0 | 17.1 | 4.1 | 23.2 | 4.8 | 7.1 | 60.8 |
| French (average) | 8 | 79.6 | .8 | 5.6 | 1.0 | .7 | 12.3 | 3.9 | 26.7 | 4.7 | 3.7 | 61.0 |
| German (average) | 5 | 75.2 | 1.2 | 6.3 | 1.4 | .9 | 15.0 | 4.7 | 25.4 | 5.4 | 3.6 | 60.9 |
| Total— | | | | | | | | | | | | |
| Minimum | ...... | 67.2 | .7 | 2.0 | .7 | .2 | 7.9 | 2.0 | 8.8 | 3.7 | 1.1 | [3] 36.7 |
| Maximum | ...... | 87.5 | 2.0 | 13.7 | 1.9 | 2.3 | 21.2 | 9.1 | [3] 49.8 | 8.1 | 8.2 | 79.4 |
| Average | 52 | 77.3 | 1.2 | 4.7 | 1.3 | .9 | 14.6 | 5.1 | 20.4 | 5.5 | 3.8 | 65.2 |
| Apple pomace:[4] | | | | | | | | | | | | |
| 1 pressing (straight) | 3 | 80.2 | .7 | 2.9 | .7 | .7 | 14.8 | 3.5 | 14.5 | 3.7 | 3.5 | 74.8 |
| 3 pressings (water added between) | 4 | 80.1 | .8 | 6.0 | 1.0 | .8 | 11.3 | 3.8 | 30.2 | 5.2 | 4.1 | 56.7 |
| Diffusion apple pomace[5] | 1 | 90.6 | .6 | 3.1 | .4 | .4 | 4.9 | 6.3 | 33.0 | 4.3 | 4.6 | 51.8 |
| All pomace: | | | | | | | | | | | | |
| Minimum | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 2.0 | 8.8 | 3.7 | 1.1 | [3] 36.7 |
| Maximum | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 9.1 | [3] 49.8 | 8.1 | 8.2 | 79.4 |
| Average | 69 | ...... | ...... | ...... | ...... | ...... | ...... | 4.9 | 20.6 | 5.5 | 3.7 | 65.3 |
| Apple-pomace silage: | | | | | | | | | | | | |
| American (average) | 5 | 81.1 | 1.1 | 4.0 | 1.5 | .9 | 11.4 | 6.3 | 21.3 | 7.9 | 4.5 | 60.0 |
| American and 2 German (average) | 7 | 70.4 | 2.0 | 6.6 | 2.4 | 1.2 | 17.4 | 6.8 | 21.9 | 8.1 | 4.3 | 58.9 |

[1] These determinations are the averages for individual samples, calculated to a moisture-free basis, and are not derived from the averages of the analyses on the original basis.

[2] Moisture-free determinations are reported on 40 samples.

[3] Reported by Houzeau. The author does not state that the straw used in pressing was included in the samples.

[4] Reported by Houzeau (*87*).

[5] Pomace was extracted by diffusion. Results reported by Houzeau (*87*).

TABLE 3.—*Miscellaneous analyses of apple pomace and apple-pomace silage (reported in the literature).*

| Product. | Number of determinations. | Composition on original basis. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Moisture. | Reducing sugars. | | Sucrose. | Degree of acidity. | Ash. | Tannin. | Reducing sugars from hydrolyzable substances. |
| | | | As invert. | As dextrose. | | | | | |
| | | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Cc. N acid per kilo.* | *Per ct.* | *Per ct.* | *Per cent.* |
| Pomace specially prepared from— | | | | | | | | | |
| Summer apples[1] | 10 | 83.3 | 5.5 | | 3.0 | 67 | 0.4 | | |
| | 1 | 80.2 | | | | | | 0.010 | |
| Fall apples | 13 | 80.8 | 6.3 | | 2.7 | 65 | .4 | | |
| | 12 | 80.7 | | | | | | .055 | |
| Winter apples | 19 | 81.0 | 6.1 | | 3.1 | 80 | .3 | .079 | |
| Crabapples | 7 | 70.9 | 6.9 | | 3.2 | 104 | .5 | | |
| | 4 | 77.0 | | | | | | .127 | |
| Apples (kind unknown)[2] | 1 | 70.8 | 8.1 | | 2.4 | 54 | .5 | | |
| Average[3] | 43 | 81.2 | 6.1 | | 2.9 | 72 | .4 | | |
| Apple pulp (English):[4] | | | | | | | | | |
| First pressing | 2 | 71.9 | | 4.4 | 2.2 | | | | |
| Second pressing | 1 | 63.4 | | 2.2 | 1.9 | | 1.7 | | |
| Apple pomace (ordinary) | 3 | 79.2 | | | | 112 | | | |
| Apple pomace (French):[5] | | | | | | | | | |
| 1 pressing (straight) | 3 | 80.2 | | | | | | | 0.80 |
| 3 pressings (exhausted) | 4 | 80.1 | | | | | | | 2.78 |
| Exhausted by diffusion | 1 | 90.6 | | | | | | | 3.02 |
| Apple pomace (slightly fermented)[7] | 1 | 75.8 | | | | | | | 5.01 |
| Apple-pomace silage | 1 | 85.3 | | | | 186 | | | |

| Product. | Number of determinations. | Moisture. | Composition on moisture-free basis. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reducing sugars as invert. | Total sugars as dextrose. | Sucrose. | Ash. | Tannin. | Pure mucilage. | Insoluble matter. | Insoluble ash. |
| | | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* |
| Pomace specially prepared from— | | | | | | | | | | |
| Summer apples[1] | 10 | 83.3 | 32.8 | | 18.0 | 2.2 | | | | |
| | 1 | 80.2 | | | | | 0.05 | | | |
| Fall apples | 13 | 80.8 | 32.9 | | 13.9 | 1.9 | | | | |
| | 12 | 80.7 | | | | | .28 | | | |
| Winter apples | 19 | 81.0 | 32.2 | | 16.3 | 1.8 | .42 | | | |
| Crabapples | 7 | 70.9 | 23.5 | | 11.1 | 1.7 | | | | |
| | 4 | 77.0 | | | | | .55 | | | |
| Apples (kind unknown)[2] | 1 | 70.8 | 27.7 | | 8.2 | 1.7 | | | | |
| Average[3] | 43 | 81.2 | 32.5 | | 15.8 | 1.9 | | | | |
| Apple pulp (English):[4] | | | | | | | | | | |
| First pressing | 2 | 71.9 | [9]16.0 | | 8.0 | | | | | |
| Second pressing | 1 | 63.4 | [9]6.1 | | 5.1 | 4.7 | | | | |
| Apple pomace (French):[5] | | | | | | | | | | |
| First pressing | | | | 23.2 | | 3.2 | .79 | 6.9 | 66.2 | 1.5 |
| Second pressing | | | | 16.3 | | 2.3 | .45 | 5.2 | 76.3 | .9 |
| Third pressing | | | | 17.5 | | 2.1 | .10 | 4.1 | 78.9 | 1.6 |
| 1 pressing (straight)[6] | 3 | 80.2 | | 32.5 | | | | | | |
| 3 pressings (exhausted)[6] | 4 | 80.1 | | 1.9 | | | | | | |
| Apple pomace (slightly fermented)[7] | 1 | 75.8 | | 13.1 | | | | | | |
| Apple pomace (German)[8] | | | | [10]24.8 | | | | | | |

[1] Analyses reported by Alwood (*36*).
[2] Analyses made on laboratory sample by Browne (*53*).
[3] Determinations on crabapple pomace are not included.
[4] Analyses reported by Allen (*34*).
[5] Analyses reported by Seguin and Pailheret (Jacquemin and Alliot) (*90*).
[6] Analyses reported by Houzeau (*87*).
[7] Analyses reported by LeChartier (*97*).
[8] Analyses reported by Mach (*108*).
[9] As dextrose.
[10] As sucrose.

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TABLE 4.—*Manurial constituents of apple pomace and apple-pomace silage (reported in the literature).*

| Product | Number of determinations. | Original basis. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Moisture. | Nitrogen (N). | Potash ($K_2O$). | Phosphoric acid ($P_2O_5$). | Lime (CaO). | Magnesia (MgO). | Soda ($Na_2O$). | Ferric oxid ($Fe_2O_3$). | Ash insoluble in acid. |
| | | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* |
| American apple pomace | 10 | 78.1 | 0.22 | 0.14 | 0.03 | ...... | ...... | ...... | ...... | ...... |
| | 2 | 80.5 | .23 | .13 | .02 | 0.04 | 0.03 | 0.03 | 0.01 | 0.01 |
| French apple pomace:[1] | | | | | | | | | | |
| 1 pressing | 3 | 80.2 | .12 | .19 | .05 | ...... | ...... | ...... | ...... | ...... |
| 3 pressings | 4 | 80.1 | .17 | .14 | .05 | ...... | ...... | ...... | ...... | ...... |

| Product | Number of determinations. | Moisture. | Moisture-free basis. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nitrogen (N). | Potash ($K_2O$). | Phosphoric acid ($P_2O_5$). | Lime (CaO). | Magnesia (MgO). | Soda ($Na_2O$). | Ferric oxid ($Fe_2O_3$). | Ash insoluble in acid. |
| | | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* |
| American apple pomace | 12 | 78.5 | 1.02 | 0.63 | 0.14 | ...... | ...... | ...... | ...... | ...... |
| | 2 | 80.5 | ...... | ...... | ...... | 0.19 | 0.14 | 0.13 | 0.04 | 0.04 |
| French apple pomace:[1] | | | | | | | | | | |
| 1 pressing | 3 | 80.2 | .59 | .94 | .26 | ...... | ...... | ...... | ...... | ...... |
| 3 pressings | 4 | 80.1 | .83 | .71 | .26 | ...... | ...... | ...... | ...... | ...... |
| Apple-pomace silage | 2 | ...... | 1.24 | 1.05 | .42 | ...... | ...... | ...... | ...... | ...... |

[1] Reported by Houzeau (*87*).

Neither the fresh nor the ensiled apple pomace was analyzed in the investigation conducted by the Bureau of Chemistry.

## DRIED APPLE POMACE.

### PREVIOUS INVESTIGATIONS.

A few chemical analyses of dried apple pomace are reported in the literature, 3 from American, 4 from French, and 4 from German sources. In addition to these, 3 analyses have been made by industrial chemists in this country, and several were made in the Bureau of Chemistry[9] in connection with the present investigation, making altogether 17 complete cattle-food analyses from which to determine the average composition of dried apple pomace. These results, together with the analysis of a partially dried mixture of apple pomace and molasses, reported by Meunier (*114*), are given in Table 5.

[9] One of the analyses was made for H. C. Gore, of the Bureau of Chemistry, in connection with his study of unfermented apple juice.

TABLE 5.—*Analyses of dried apple pomace and of air-dried pomace molasses mixture (reported in the literature).*

| Product. | Number of determinations. | Composition on original basis. | | | | | | Composition on moisture-free basis. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Moisture. | Ether extract. | Crude fiber. | Crude protein. | Ash. | Nitrogen-free extract. | Ether extract. | Crude fiber. | Crude protein. | Ash. | Nitrogen-free extract. |
| Dried apple pomace: | | | | | | | | | | | | |
| American— | | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| Minimum | ...... | 5.5 | 1.8 | 14.6 | 3.3 | 1.8 | 50.4 | 2.0 | 16.0 | 3.9 | 2.0 | 58.2 |
| Maximum | ...... | 15.8 | 5.6 | 25.7 | 6.6 | 2.8 | 69.4 | 6.0 | 29.7 | 7.1 | 3.0 | 75.8 |
| Average[1] | 9 | 8.6 | 3.8 | 18.8 | 4.6 | 2.3 | 61.9 | 4.2 | 20.6 | 5.0 | 2.5 | 67.7 |
| French— | | | | | | | | | | | | |
| Minimum | ...... | 11.4 | 3.8 | 18.2 | 4.2 | 3.5 | 53.9 | 4.3 | 20.7 | 4.8 | 4.0 | 61.6 |
| Maximum | ...... | 13.2 | 4.7 | 21.0 | 5.0 | 4.0 | 57.2 | 5.3 | 24.0 | 5.7 | 4.6 | 65.1 |
| Average | 4 | 12.3 | 4.1 | 19.6 | 4.6 | 3.7 | 55.7 | 4.7 | 22.3 | 5.3 | 4.3 | 63.4 |
| German— | | | | | | | | | | | | |
| Minimum | ...... | 10.0 | 3.2 | 16.8 | 4.0 | 2.1 | 49.1 | 3.6 | 20.5 | 4.4 | 2.4 | 57.6 |
| Maximum | ...... | 18.0 | 3.6 | 21.4 | 6.3 | 5.8 | 59.1 | 4.4 | 25.1 | 7.7 | 6.8 | 66.7 |
| Average | 4 | 14.3 | 3.4 | 19.1 | 5.3 | 3.4 | 54.5 | 4.0 | 22.2 | 6.2 | 4.0 | 63.6 |
| All— | | | | | | | | | | | | |
| Minimum | ...... | 5.5 | 1.8 | 14.6 | 3.3 | 1.8 | 49.1 | 2.0 | 16.0 | 3.9 | 2.0 | 57.6 |
| Maximum | ...... | 18.0 | 5.6 | 25.7 | 6.6 | 5.8 | 69.4 | 6.0 | 29.7 | 7.7 | 6.8 | 75.8 |
| Average | 17 | 10.8 | 3.8 | 19.0 | 4.8 | 2.9 | 58.7 | 4.3 | 21.4 | 5.3 | 3.3 | 65.7 |
| Apple-pomace-molasses mixture[2] | 1 | 34.8 | 3.5 | 10.6 | 4.0 | 6.5 | 40.6 | 5.4 | 16.3 | 6.1 | 10.0 | 62.2 |

[1] Three lots of American apple pomace with an average moisture content of 10.3 per cent had an average acidity of 198 cc. N acid per kilo.
[2] This mixture was air-dried and consisted of 1 part of pomace to 1 part of molasses, as reported by Meunier (*114*).

## PRESENT INVESTIGATION.

Two representative samples of commercially evaporated apple pomace were analyzed in the Bureau of Chemistry. The first (sample 37199) was produced in a small mill and was only partially dried. It had an odor indicative of slight fermentation when received in the laboratory, but otherwise it appeared to be in good condition. The other (sample 37254) was part of a 400-pound lot obtained from another mill for use in the feeding trial reported on pages 27 to 29. This product, which was thoroughly dried and perfectly sweet and sound, is typical of pomace which has been properly dehydrated, at moderate heat, to serve as the source of commercial pectin or apple base for jelly stock. The material analyzed was dried in a steam-heated rotary pomace dryer (p. 6).

### CHEMICAL EXAMINATION.

The methods of analysis of the Association of Official Agricultural Chemists were followed, except for the modifications noted.

*Moisture* was determined directly by drying the sample to constant weight in a vacuum oven at 65° to 70° C. The vacuum gauge registered between 24 and 28 inches.[10] A slight flow of air, dried by concentrated sulphuric acid, was maintained through the oven, to sweep out the water vapor.

*Crude protein.*—The nitrogen[11] was determined in the nitrogen section of the Bureau of Chemistry by the Kjeldahl-Gunning-Arnold method and the figure thus obtained was multiplied by 6.25.

[10] The equivalent of atmospheric pressure, minus the pressure of the oven, measured in inches of mercury.
[11] Organic and ammoniacal nitrogen.

*Ether extract* (*crude fat*) was determined by the official method, both without previous extraction of the material with cold water and after such extraction and subsequent drying. The higher results, obtained without extracting with water, are the ones reported.

*Crude fiber.*—Properly prepared asbestos was mixed with the charge in both the acid and alkali digestions. This was practically necessary because of the slowness of filtration. Even with the asbestos present and serving to render the residue more porous, the second filtration, after the alkali digestion, was very slow.

*Nitrogen-free extract.*—The percentage of nitrogen-free extract was obtained by subtracting the sum of the moisture, crude protein, ether extract, crude fiber, and ash percentages from 100.

*Reducing sugars and sucrose.*—The Bryan-Given-Straughn method for total (reducing and nonreducing) sugars, applicable to cattle foods (*7*), was followed, but it was modified in the case of the initial charge and the aliquots used.

*Starch* was determined by the official malt diastase method, modified as follows: Twenty-five per cent alcohol, instead of 10 per cent alcohol, was used for extracting sugars and other interfering soluble carbohydrates. For the first digestion of the gelatinized starch with malt extract, after adding the infusion the temperature was raised gradually to 70° C. instead of 55° C. and maintained at this temperature for 30 minutes, the total time of heating being about 1 hour.[12] After the acid hydrolysis, phosphotungstic acid solution [13] was added to defecate the cold acid dextrose solution. When it had been filtered to eliminate precipitated impurities, an aliquot was neutralized, after which the usual procedure was followed.

Recent work on the determination of starch in the presence of interfering polysaccharides, such as pectin, has indicated that correct results may be obtained by using 60 per cent alcohol to eliminate the interfering substances. Immediately after the malt digestion alcohol is added, a little at a time, with constant mixing, until the concentration reaches 60 per cent. An aliquot of the filtrate is evaporated over steam until the aqueous residue is practically free from alcohol. This residue is taken up with hot water and subjected to acid hydrolysis, etc. (J. Agr. Research, vol. 23, No. 12 (1923), p. 995).

*Degree of acidity* (*total titrable acidity*) was determined on a water extract and on an 80 per cent alcohol extract of the material, essentially following the tentative method of the Association of Official Agricultural Chemists (*7*). The extracts were obtained by violently stirring the charge and solvent in a four-sided 8-ounce glass jar for 30 minutes by means of an electric mixer.[14] In the case of the water extract, distilled water, previously boiled and cooled, was used. The total acidity, expressed as cubic centimeters of normal "acid" per kilogram of material, is termed the "degree of acidity."

*Specific acidity* (*hydrogen-ion concentration*) *of the water and alcoholic extracts.*—The specific acidity (hydrogen-ion concentra-

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[12] While the conversion of starch into sugars is not as complete by this procedure as by digestion at 55° C., the starch is rendered soluble much more effectively, and with the second digestion conducted at 55° C., as in the original method, uniformly better results have been obtained in the Bureau of Chemistry.

[13] Two cubic centimeters of a 10 per cent solution of phosphotungstic acid in 1 per cent hydrochloric acid.

[14] Described in U. S. Dept. Agr. Off. Sec. Circ. 68.

tion) was estimated on a portion of the clear extract [15] by a slight modification of the colorimetric method described by Gillespie (*12*), taken from Barnett and Chapman (*9*), in which use is made of the principle introduced by Clark and Lubs (*11*), following Salm (*14*), of "superimposing the two extreme colors of an indicator in determining its half-transformation point." Instead of using a system of 9 pairs of tubes, having drop-ratios 1:9, 2:8, etc., Medalia's system (*13*) of 7 pairs, having pH exponent intervals of 0.2 between each pair for the indicators used, was adopted. Briefly, the procedure is as follows: [16]

Make the color comparisons in the small "block" comparator described by Gillespie. Calibrate 7 pairs of test tubes, selected to fit the comparator and for their uniformity in bore, for 5 cubic centimeter capacity, and arrange in a double-row test-tube rack. Into each pair of tubes deliver a total of 8 drops of the suitable indicator solution, from 1 to 7 drops in each of the 7 front tubes, and from 7 to 1 drops in each tube in the rear row, taking the precaution to hold the delivery pipette in an upright position. Add enough alkali [17] (dilute acid in the case of the indicator thymol blue, acid range) to the tubes in the front row to produce the full alkaline color and enough acid [17] to those in the back row to develop the acid color; then fill to the 5 cubic centimeter mark with distilled water, previously boiled and cooled. Similar tubes are used for the solutions under examination (the water extracts of the pomace). Eight drops of the indicator solution is, of course, required, and the 5 cubic centimeter volume is completed with the unknown solution. Mix well [18] the contents of all tubes before making the color comparisons.

In making the color comparisons arrange the tubes, held vertically in the comparator, in two files of three tubes each. One file includes the tube containing the unknown, with indicator solution, and two tubes of distilled water. The other file consists of a pair of the standard tubes and a tube containing the unknown solution, without indicator. This arrangement is necessary, on the one hand, to obviate optical differences caused by the thickness of the liquid viewed, and, on the other, to offset the natural color and any turbidity of the extract under examination. Try different pairs of standards until the color of light passing horizontally through that file of tubes matches the color from the file containing the tube of unknown with indicator.

As stated by Gillespie (*12*), the tubes are best viewed against the sky. Occasionally in the case of certain indicators, such as bromphenol blue, trouble is experienced in matching the colors because of a dichroic effect, especially noticeable in turbid solutions. In such cases the tubes may be viewed by the yellow light of a carbon electric lamp screened as advised by Clark and Lubs.

Only two indicator solutions were needed in estimating the specific acidity of the pomace extracts, a 0.05 per cent aqueous solution of bromphenol blue [19] and a 0.02 per cent solution of thymol blue (thymolsulphonephthalein) in 80 per cent alcohol.

To develop the full acid and alkaline colors, respectively, in the standard paired tubes the following quantities of reagents were used for the two indicators:

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[15] Not necessarily the same extract used for the total acidity determination, but one for which this had been determined.

[16] A much simpler but less accurate color comparison may be made on an ordinary porcelain spot-plate, using 5 drops of extract and 1 drop of indicator solution. The color is matched against standard buffer solutions of known pH, or in the absence of these it may be compared with the colors in Wherry's chart (*18*).

[17] The quantity of alkali or acid varies somewhat for the different indicators.

[18] Mixing may be accomplished by rolling the tube back and forth between the palms of the hands.

[19] Tetrabromophenolsulphonephthalein. The 0.05 per cent solution was prepared by diluting 1 volume of the indicator solution furnished in the LaMotte field set to 20 volumes with freshly boiled and cooled distilled water.

*Bromphenol blue.*—To produce the acid color, 0.5 cubic centimeter of N/10 hydrochloric acid solution; to produce the alkaline color, 1 drop of N/20 sodium hydroxid solution.

*Thymol blue (acid range).*—To produce the full acid color, 2 cubic centimeters of 1.25 per cent hydrochloric acid solution; to produce the color of the alkaline end of the range, 1 cubic centimeter of 0.005 per cent (N/700) hydrochloric acid solution.

The volume in all the tubes should be made up at once to 5 cubic centimeters.

The specific-acidity[20] values accepted for the several drop-ratios are given in Table 6. These specific-acidity and pH values, while not exact, are close enough for the purposes of this investigation.

TABLE 6.—*Specific acidity and pH values for indicators used.*

| Drop-ratio. | Bromphenol blue. | | Thymol blue (acid range). | |
|---|---|---|---|---|
| | Specific acidity.[1] | pH. | Specific acidity.[1] | pH. |
| 1:7 | 6,300 | 3.2 | 400,000 | 1.4 |
| 2:6 | 4,000 | 3.4 | 250,000 | 1.6 |
| 3:5 | 2,500 | 3.6 | 160,000 | 1.8 |
| 4:4 | 1,600 | 3.8 | 100,000 | 2.0 |
| 5:3 | 1,000 | 4.0 | 63,000 | 2.2 |
| 6:2 | 630 | 4.2 | 40,000 | 2.4 |
| 7:1 | 400 | 4.4 | 25,000 | 2.6 |

[1] In round numbers.

The color standards are quite permanent, and if stoppered and kept in the dark the tubes may be used over a long period of time (*13*, p. 451). Reference articles (particularly *12* and *13*) contain details on the use of indicators covering pH values from 1.2 to 9.8. All determinations were made at room temperature, about 25°C.

*Hydrocyanic acid.*—The determinations of available hydrocyanic acid were made by the method used by Viehoever for the hydrolysis of linamarin and the subsequent determination of hydrocyanic acid (*17*).[21] Because of the evident absence of the enzyme emulsin (as shown by negative results when the samples were macerated with water alone), however, other determinations were made in which emulsin was added, to insure the hydrolysis of any amygdalin present. The estimation of hydrocyanic acid in the distillate was made by the Volhard method and by the method of Viehoever and Johns.

## RESULTS OF CHEMICAL EXAMINATION.

Table 7 shows the chemical composition of the dried apple pomace analyzed and that of corn silage with which it was later compared in the feeding tests (p. 27). The slight difference between the ether extract and protein results for sample 37254 in the original condition and those for the same sample after the seeds had been removed indicates the presence of an appreciable quantity of fine seed

[20] Specific acidity is based on the hydrogen-ion concentration of pure neutral water as unity, as defined by Wherry (*18, 19*).

[21] Miss Ruth G. Capen, in the pharmacognosy laboratory of the Bureau of Chemistry, made these determinations.

material in the "seedless" sample. The results given for the edible pulp, skin, and seeds of the apple in Table 1 are interesting in this connection.

TABLE 7.—*Composition of dried apple pomace and of corn silage.*

| Product. | Sample No. | Moisture at 65°–70° C. | Ash. | Ether extract. | Crude protein (N x 6.25). | Crude fiber. | Nitrogen-free extract. | Pentosans. | Reducing sugars as invert.[1] | Nonreducing sugars as sucrose. | Starch (diastase method). | Degree of acidity. | Water-insoluble substance. | Water-insoluble crude protein. | Alcohol precipitate (pectins). | Total hydrocyanic acid (HCN). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *Cc. N acid per kilo.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| Dried apple pomace | [2]37199 | 15.75 | 2.48 | 3.87 | 3.31 | 16.58 | 58.01 | 11.4 | 5.24 | 0.28 | ..... | 188 | ..... | ..... | ..... | 0.000 |
| Dried apple pomace (400-pound sample tested) | 37254 | 6.64 | 2.79 | 5.64 | 6.63 | 20.14 | 58.16 | 13.5 | 11.12 | 1.44 | 6.8<br>3.8 | 232 | 60.13 | 5.81 | 10.6 | .001 |
| Dried apple pomace (sample 37254 after removal of seeds) | 37735 | 7.74 | 3.21 | 4.53 | 5.17 | 20.6 | 58.75 | 13.6 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | .000 |
| Dried apple pomace (sample 37254) mixed with 3 times its weight of water[4] | ..... | 76.7 | .7 | 1.4 | 1.7 | 5.0 | 14.5 | 3.4 | 2.8 | .4 | 1.7<br>[3].9 | 58 | 15.0 | 1.5 | 2.6 | ..... |
| Corn silage (average)[5] | 36873<br>37157 | 73.3 | 1.4 | .8 | 1.7 | 7.0 | 15.8 | 4.8 | ..... | ..... | ..... | [6]340 | ..... | ..... | ..... | ..... |

[1] Browne (*53*) has reported that the ratio of levulose to dextrose is approximately 2 to 1.
[2] This sample was obtained from a small mill.
[3] Obtained by the 60 per cent alcohol purification method.
[4] This was the material actually fed. The figures representing its composition were calculated.
[5] These samples were taken from a different silo than the silage actually used in the comparison.
[6] Nonvolatile, 150.

The determination of starch by the malt-diastase method for products of this nature is not entirely satisfactory. The results thus obtained are believed to be too high, but in the absence of proof that this is the case, they have been accepted. Much lower results for starch were obtained by Cassal's colorimetric method (*10*). The difference in the quality of the colors of the standard and the pomace extract was so great, however, that no dependence was placed on the comparison.

The result obtained by the 60 per cent alcohol purification method probably more nearly represents the actual starch content of the pomace examined.

The constituent termed "nitrogen-free extract" includes starch, sucrose, reducing sugars, pentosans, most, if not all, of the pectin compounds, organic acids not soluble in ether, and certain other ingredients present in small quantities.

Nearly six times as much total acid-reacting substance per pound of succulence fed is ingested in the case of the corn silage as in the case of the pomace mash. The effect of "acidity" in a food, however, is measured not so truly by the total quantity of acid-reacting substances present as by the intensity factor or "strength" of the acid, the quantity that is actually and instantly available. The "strength" or intensity value of an acid is determined solely by the quantity of hydrogen ion (dissociated acid) it contains, termed the hydrogen-ion concentration.[22] For comparison this intensity

[22] "$H^+$" is the symbol for hydrogen ion.

value, or $H^+$ concentration, is stated in terms based on the $H^+$ concentration of pure neutral water [23] as unity. It may be stated directly in whole numbers as "specific acidity," or, as is done more frequently, as the logarithm of the reciprocal of the actual concentration, generally designated by the symbol pH.

The data on the specific acidity of extracts of the materials used in this investigation (Table 8) are of value not only in determining the "strength" of the acid-reacting compounds in the apple products but also in indicating the identity of these "acids."

TABLE 8.—*Acidity of extracts of dried apple pomace, dried pectin pulp, corn silage, and dried beet pulp.*

| Product extracted. | Sample No. | Quantity of sample per 100 cubic centimeters of extract. | Total acidity per 100 cubic centimeters of extract. | Hydrogen-ion concentration. Of extract examined. (Observed.) | | Of aqueous solution of "pure" acid of same total acidity.[1] Acid potassium malate ($HKC_4H_4O_5$). (Computed.) | Malic acid ($H_2C_4H_4O_5$). (Computed.) |
|---|---|---|---|---|---|---|---|
| | | *Grams.* | *Cc. N acid.* | *Specific acidity.*[2] | *pH.* | *pH.* | *pH.* |
| Dried apple pomace (80 per cent alcohol extract) | 37199 | 13.3 | 2.505 | 10,000 | 3.0 | 3.36 | 2.39 |
| Dried apple pomace (400-pound sample): | | | | | | | |
| 80 per cent alcohol extract | 37254 | 4.0 | .928 | 10,000 | 3.0 | 3.58 | 2.63 |
| Aqueous extract | 37254 | 5.0 | .667 | 10,000 | 3.0 | 3.65 | 2.72 |
| Corn silage (moisture content, 71.4 per cent) (80 per cent alcohol extract) | 36873 | 9.3 | 3.100 | 2,500 | 3.6 | ...... | ...... |
| Corn silage (moisture content, 75.3 per cent) (80 per cent alcohol extract) | 37157 | 9.3 | 3.240 | 5,000 | 3.3 | ...... | ...... |
| Dried apple-pectin pulp (400-pound sample): | | | | | | | |
| 80 per cent alcohol extract | 36675 | 10.0 | 2.420 | 6,300 | 3.2 | 3.37 | 2.39 |
| Aqueous extract | 36675 | 10.0 | 1.900 | 4,000 | 3.4 | 3.42 | 2.45 |
| Dried apple-pectin pulp (unground) (80 per cent alcohol extract) | 37373 | 4.0 | 1.248 | 10,000 | 3.0 | 3.52 | 2.56 |
| Dried apple-pectin pulp (2-ton sample) (80 per cent alcohol extract) | 37866 | 4.0 | .992 | 6,300 | 3.2 | 3.57 | 2.61 |
| Dried beet pulp: | | | | | | | |
| 80 per cent alcohol extract | 37867 | 4.0 | .192 | 6,300 | 3.2 | ...... | ...... |
| Aqueous extract | 37867 | 5.0 | .105 | 800 | 4.1 | ...... | ...... |

[1] Computed for an aqueous solution of "pure" acid having the same total acidity as the extract examined.
[2] In round numbers.

Bigelow and Dunbar (*44*) have shown that free malic acid is the source of acidity in apples. The treatment to which the fruit is subjected in obtaining dried pomace, however, permits of fundamental changes in the character of the "acidity" during the process of manufacture.

By comparing the pH exponents (Table 8) determined colorimetrically on the dried pomace extracts with those computed for pure solutions of acid potassium malate and free malic acid, it is apparent that if malic acid is principally responsible for the acidity, a

[23] "Neutral" water as measured by its conductivity. Careful experimentation has shown that a liter of such water dissociates to the extent of containing 0.0000001 gram of $H^+$ or $10^{-7}$ gram; hence its pH value (the pH of the neutral point) is 7.

sufficient quantity of soluble basic salts or other reactive substances must be present to exert a strong buffer action.[24] It is even probable that the pectin substances could exert a buffer effect of this magnitude. At any rate, the effect in solution is that of free malic acid buffered by some malate. For the normality involved the specific acidity of a malic-acid solution is approximately ten times that of a solution of the acid malate. The pH values in the last two columns of Table 8 for acid potassium malate and malic acid were computed by the help of the following formula, derived from Ostwald's Dilution Law, as explained in detail by Thomas (*16*) :[25]

$$\text{Per cent ionization} = 100\left(\sqrt{KV} - \frac{KV}{2}\right).$$

$V$=volume in liters, in which 1 gram-molecular weight[26] of the substance is dissolved.

$K$=the dissociation constant (the values given for $Ka$ in Scudder's (*15*) tables).

The pH values as thus computed are based on conductivity data and not on measurements by the hydrogen electrode. Therefore they should not be accepted as absolute.

Investigation of the amygdalin, or more precisely the hydrocyanic acid, content of dried pomace was undertaken because of the well-known fact that ripe apple seeds contain important quantities of this toxic substance. Huber (*88*) has reported the presence of from 0.62 to 1.38 per cent of amygdalin, corresponding to from 0.037 to 0.082 per cent of hydrocyanic acid, in the dry substance of apple seeds. Auld (*8*) found that as little as 3.9 grains of hydrocyanic acid was fatal to an 80-pound sheep when taken in the form of potassium cyanide. Corresponding to Huber's highest figure in hydrocyanic acid content, 5.74 grains of hydrocyanic acid would be contained in 1 pound of seeds.

Examination of the dried pomace, however, indicated an entire absence of emulsin, the enzyme occurring in apple seeds (*88*), which serves to generate free hydrocyanic acid from the glucoside amygdalin.

Sample 37199 gave a negative test for hydrocyanic acid, even when the enzyme was added to the macerated material. The quantity of seeds present may have been so small that any acid formed on maceration was not sufficient to give the test, or the method of preparing the pomace may have been such that the cyanophoric compound was changed and did not yield hydrocyanic acid.

In the examination of sample 37254, the material used in the feeding trial, the seeds were separated by hand from the remainder of the pomace and tested separately. The seeds constituted 5 per cent by weight of the sample, and, with added emulsin, yielded 0.020 per cent of hydrocyanic acid, corresponding to 0.38 per cent of amygdalin. This is equivalent to 0.001 per cent of hydrocyanic acid in the dried pomace. The pomace material from which the seeds had been removed gave a negative test for hydrocyanic acid.

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[24] Buffer action in this case means the power to depress the formation of hydrogen ions.

[25] By an evident typographical error in Thomas' article this formula was incorrectly stated: "Per cent ionization=100 $\sqrt{KV} - \frac{KV}{2}$."

[26] One gram-molecule.

While there is an appreciable quantity of hydrocyanic acid in the seeds, so long as the liberating enzyme is eliminated in the process of manufacture, as evidently occurred in this sample, there should be no danger from feeding reasonable quantities of dried pomace such as this. Auld (*8*) has shown that the liberation of hydrocyanic acid from similar glucosides is retarded in normal digestion, even in the presence of the glucosidoclastic enzyme. On the other hand, fermented, moldy, or yeast-containing feeds generally contain enough of the enzyme to supply any deficiency, so that the safest course is to see that precautions are taken by the manufacturer of the dried pomace to eliminate not only the enzyme but the cyanophoric glucoside. This could be accomplished either by removal of most of the seeds or by first "digesting" the moist press cake in a warm place for several hours, then thoroughly cooking the pomace during or, preferably, before drying.

The possibility of turning to good account the substance that may make the presence of the seeds in a feed dangerous is worthy of some consideration. For example, it has been shown that apple seeds contain from 0.62 to 1.38 per cent of amygdalin, which, in the kernels of bitter almonds, is the source of the volatile oil of that name. Bitter almonds are reported to contain from 1 to 3 per cent of amygdalin, and other seed kernels, recommended as a source of the volatile oil, contain from 1.5 to 3 per cent (*123*, *124*). After decomposition of the amygdalin and removal of the volatile oil from apple seeds the thoroughly heated and dried residues might prove to have some value as a feed.

It has been suggested that material containing such large quantities of pectin substances as dried apple pomace might cause injury if fed in excess, owing to the formation of methyl alcohol from the pectin.[27] Fellenberg (*65*) reported that he obtained methyl alcohol from the digestion of foods containing pectin, and Tutin (*133*) has shown that not only methyl alcohol but acetone is liberated from pectin by the action of the enzyme pectase and also of cold dilute alkali on pectin. Here again, however, heating the material thoroughly in a moist condition would serve to destroy the liberating enzyme if it were present in the pomace. Considering the large quantity of pectin consumed daily by animals and by man, injury from this source appears very remote.

### DRIED APPLE-PECTIN PULP.

Several apple residues intermediate in composition between straight apple pomace and apple-pectin pulp are obtained by subjecting the straight pomace to a second or third pressing, with or without the addition of water and soaking between pressings (p. 8). To avoid confusion, "apple-pectin pulp," synonymous with "extracted apple pomace," is here applied only to the product which remains after treating the original dried apple material, whether chops, waste, or dried pomace, with cold water to remove sugars and other soluble substances, and subsequently extracting the

[27] A portion of dried pomace (sample 37254), subjected to destructive distillation in a copper retort, yielded 1.5 per cent methyl alcohol and over 2 per cent acetic acid. This work was done by W. F. Sterling, in the leather and paper laboratory of the Bureau of Chemistry.

pectin with boiling water or steam. There are but few references in the literature to such apple-pectin pulp, either moist or dried. Alwood (*35*) in a general way pointed out the economic loss involved, because of their sugar and pectin content, in allowing cider press residues to go to waste. In 1899 Browne (*53*) called attention to the profits to be derived from the utilization of "second pressings." He stated that the residue may still be used as feed or for other purposes.

The only analyses of apple-pectin pulp in the literature are those of Shutt (*129*). Two analyses of this product were received from industrial chemists and several were made in the Bureau of Chemistry. Table 9 shows the composition of commercially dried pectin pulp, moist pectin pulp, and a dried mixture of molasses and extracted pomace and the pulp from which it was obtained.

TABLE 9.—*Average composition of moist and dried apple-pectin pulp (extracted apple pomace) and of dried pulp-molasses mixture.*

| Product. | Composition on original basis. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Moisture. | Ether extract. | Crude fiber. | Crude protein. | Ash. | Nitrogen-free extract. | Degree of acidity. | Reducing sugars as invert. | Sucrose. | Total sugars. |
| | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *Cc. N acid per kilo.* | *P. ct.* | *P. ct.* | *P. ct.* |
| Moist pectin pulp (Canada)[1] | 85.1 | 0.7 | 4.7 | 1.4 | 0.4 | 7.7 | ...... | ...... | ...... | ...... |
| Moist pectin pulp (American) (sample 29155) | 75.0 | 1.7 | 10.5 | 2.2 | 1.1 | 9.5 | 45 | 1.8 | 0.1 | 1.9 |
| Moist pectin pulp (American, from peelings and cores) (sample 26313) | 88.0 | .7 | 3.5 | .9 | .3 | 6.6 | ...... | ...... | ...... | ...... |
| Dried pectin pulp (American): | | | | | | | | | | |
| Factory dried (6 samples) | 8.8 | 7.3 | 24.2 | 7.0 | 3.3 | 49.4 | ...... | ...... | ...... | ...... |
| Miscellaneous (6 samples) | 8.0 | ...... | ...... | ...... | ...... | ...... | 215 | ...... | ...... | ...... |
| Miscellaneous (4 samples) | 8.4 | ...... | ...... | ...... | ...... | ...... | ...... | 4.3 | .4 | 4.7 |
| Dried pectin-pulp-molasses mixture (sample 29963)[2] | 10.0 | 4.4 | 26.9 | 6.7 | 5.1 | 46.9 | ...... | 9.7 | 12.9 | 22.6 |

| Product. | Composition on moisture-free basis. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Moisture. | Ether extract. | Crude fiber. | Crude protein. | Ash. | Nitrogen-free extract. | Reducing sugars as invert. | Sucrose. | Total sugars. |
| | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P.* |
| Moist pectin pulp (American) (sample 29155) | 75.0 | 6.9 | 42.0 | 8.9 | 4.2 | 38.0 | 7.1 | 0.3 | 7.4 |
| Dried pectin pulp (American): | | | | | | | | | |
| Factory dried (6 samples) | 8.8 | 8.0 | 26.5 | 7.7 | 3.6 | 54.2 | ...... | ...... | ...... |
| Miscellaneous (4 samples) | 8.4 | ...... | ...... | ...... | ...... | ...... | 4.7 | .4 | 5.1 |
| All pectin pulp: | | | | | | | | | |
| Minimum | ...... | 4.8 | 22.0 | 7.2 | 2.5 | 37.9 | ...... | ...... | ...... |
| Maximum | ...... | 9.7 | 42.0 | 9.5 | 4.7 | 58.3 | ...... | ...... | ...... |
| Average (9 samples) | ...... | 7.3 | 29.1 | 8.0 | 3.5 | 52.1 | ...... | ...... | ...... |
| Dried pectin-pulp-molasses mixture (sample 29963)[2] | 10.0 | 4.9 | 29.9 | 7.4 | 5.7 | 52.1 | 10.8 | 14.3 | 25.1 |

[1] Reported by Shutt (*129*).

[2] This sample was prepared from sample 29155 (89 per cent) and molasses (11 per cent), dried to a moisture content of 10 per cent, equivalent to 2 parts of moisture-free pomace to 1 part of blackstrap molasses. The figures representing the composition of the mixture were calculated.

Apple-pectin pulp was first brought to the attention of the Department of Agriculture by a manufacturer who found this so-called "extracted apple pomace" a waste product and its disposal a source of annoyance. A representative sample of the fresh, moist residue was analyzed. Later a sample of the dried product was received from another manufacturing company, which proposed putting it on the market as a stock food, under the name of "dried apple-pectin pulp," and had equipped a plant for that purpose.

Representative subsamples (Nos. 36675 and 37866) of the two lots of dried pulp used in the feeding experiments were analyzed in the same way as the dried pomace samples (p. 11). These lots of the feed, which were sound and sweet and had been well dried, may be considered to be fairly representative of commercially dried apple-pectin pulp.

Table 10 gives the data obtained in the chemical examination of the dried pectin pulp, as well as those obtained in the examination of the dried beet pulp with which the pectin pulp was compared in the milk-production test (p. 30), with the exception of the specific acidities of the extracts which are included in Table 8. As the pectin pulp and the beet pulp were mixed with three times their weight of water before being fed, calculated values showing the composition of the respective "mashes" are given in Table 10. The composition of the corn silage with which the pectin pulp was compared in the preliminary trial is also included.

TABLE 10.—*Composition of dried apple-pectin pulp, dried beet pulp, and corn silage.*

| Product. | Sample No. | Moisture at 65°–70°C. | Ash. | Ether extract. | Petroleum-ether extract.[1] | Crude protein. | Albuminoids. | Crude fiber. | Nitrogen-free extract. |
|---|---|---|---|---|---|---|---|---|---|
| | | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| Dried apple-pectin pulp (not ground at factory) | 37373 | 5.86 | 3.37 | 7.91 | ...... | 7.13 | ...... | 28.50 | 47.23 |
| Dried apple-pectin pulp with seeds removed (from sample 37373) | 37736 | 6.94 | 3.28 | 7.57 | ...... | 6.81 | ...... | 27.66 | 47.74 |
| Dried apple-pectin pulp (400-pound lot) | 36675 | 9.28 | 2.98 | 6.19 | 3.07 | 6.88 | 6.25 | 24.13 | 50.54 |
| Dried apple-pectin pulp (2-ton lot) | 37866 | 9.86 | 3.85 | 6.90 | ...... | 7.13 | ...... | 25.60 | 46.66 |
| Dried beet pulp | 37867 | 10.30 | 3.38 | .54 | ...... | 8.25 | ...... | 19.59 | 57.94 |
| Dried apple-pectin pulp (sample 36675) mixed with 3 times its weight of water,[2] as fed | ...... | 77.30 | .70 | 1.60 | 0.80 | 1.70 | 1.60 | 6.00 | 12.70 |
| Corn silage, as fed | 36873, 37157 | 73.30 | 1.40 | .80 | .50 | 1.70 | ...... | 7.00 | 15.80 |
| Dried apple-pectin pulp (sample 37866) mixed with 3 times its weight of water,[2] as fed | ...... | 77.50 | 1.00 | 1.70 | ...... | 1.80 | ...... | 6.40 | 11.60 |
| Dried beet pulp (sample 37867) mixed with 3 times its weight of water,[2] as fed | ...... | 77.60 | .80 | .10 | ...... | 2.10 | ...... | 4.90 | 14.50 |

[1] More nearly true fat than ether extract.
[2] The results reported for this sample were calculated.

TABLE 10.—*Composition of dried apple-pectin pulp, dried beet pulp, and corn silage*—Continued.

| Product. | Sample No. | Pentosans. | Reducing sugars as invert. | Nonreducing sugars as sucrose. | Starch (diastase method). | Degree of acidity. | Water-insoluble substance. | Water-insoluble crude protein. | Alcohol precipitate. | Total hydrocyanic acid (HCN). |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *Cc. N acid per kilo.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| Dried apple-pectin pulp (not ground at factory) | 37373 | 13.10 | ...... | ...... | ...... | 312 | ...... | ...... | ...... | [3] 0.00 |
| Dried apple-pectin pulp with seeds removed (from sample 37373) | 37736 | 11.60 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | .00 |
| Dried apple-pectin pulp (400-pound lot) | 36675 | 12.70 | 4.66 | 0.44 | ...... | 242 | ...... | ...... | ...... | .00 |
| Dried apple-pectin pulp (2-ton lot) | 37866 | 12.20 | 3.52 | .43 | 6.1; [4] 2.4 | 248 | 68.91 | 6.88 | 9.30 | [5] .00 |
| Dried beet pulp | 37867 | 26.40 | .35 | 1.35 | ...... | 48 | ...... | ...... | ...... | ...... |
| Dried apple-pectin pulp (sample 36675) mixed with 3 times its weight of water,[2] as fed | ...... | 3.20 | 1.20 | .10 | ...... | 60 | ...... | ...... | ...... | ...... |
| Corn silage, as fed | 36873; 37157 | 4.80 | ...... | ...... | ...... | [6] 340 | ...... | ...... | ...... | ...... |
| Dried apple-pectin pulp (sample 37866) mixed with 3 times its weight of water,[2] as fed | ...... | 3.00 | .90 | .10 | 1.5; [4] .6 | 62 | 17.20 | 1.70 | 2.30 | ...... |
| Dried beet pulp (sample 37867) mixed with 3 times its weight of water,[2] as fed | ...... | 6.60 | .10 | .30 | ...... | 12 | ...... | ...... | ...... | ...... |

[2] The results reported for this sample were calculated.
[3] Although the test on the whole sample gave a negative result, a separate test on the seeds (2 per cent of the sample) gave a positive result.
[4] Obtained by the 60 per cent alcohol purification method.
[5] This sample contained a very small quantity of seed tissue which, when tested separately with added emulsin, gave a positive result.
[6] Nonvolatile, 150.

The similarity in composition between the pectin pulp, moistened as fed, and the corn silage is striking, if the acidity be excepted. While the result for ether extract in the pectin pulp is twice that in the silage, the true fat content, gauged by the petroleum-ether extract, is but little greater. The beet pulp "mash" is higher in crude protein, although lower in albuminoids, but contains practically no fat and a negligible quantity of sucrose. Albuminoid nitrogen in the one sample of pectin pulp tested for it constituted over 90 per cent of the total nitrogen. This agrees well with corresponding data found in the literature for apple pomace (*79, 108*).

The malt-diastase determination of starch was no more satisfactory for dried pectin pulp than for dried pomace, nor was the colorimetric method reliable. The results obtained by the 60 per cent alcohol purification method probably more nearly represent the true starch content.

The sample from which seeds had been separated, like the corresponding dried pomace sample, still contained fine seed tissue, judging by the ether extract and protein contents. This fine seed material probably had lost its cyanogenetic property, as in ruptured seed tissues, particularly when moist, such reactions are soon completed, and any hydrocyanic acid formed would have been eliminated in the drying process.

The degree of (total) acidity ranges from 12, for the moist beet pulp, to 340, for the corn silage, with the pectin pulp "mash"

occupying a mean position at 60 to 62. On the other hand, the specific acidity values of the extracts lie within rather narrow limits, that for the corn silage extract being the lowest. The alcoholic extract of the dried beet pulp, very weak as to total acidity, shows a remarkably high hydrogen-ion concentration, indicating over 30 per cent ionization, while the aqueous extract has an indicated ionization of 7.5 per cent.[28] Solving for $K$ in the ionization formula (p. 17), assuming the acid to be monobasic, yields approximately $5\times10^{-3}$ for the alcoholic extract and $3.9\times10^{-3}$ for the water extract, values higher than those given in Scudder's tables for any common organic acid except oxalic. This indicates the presence of a "strong" acid in dried beet pulp.[29]

From the feeder's standpoint, then, the available acid in the beet pulp "mash" was more nearly equal to that in the moistened pectin pulp than would appear from an ordinary acidity titration.

Examination of the dried pectin pulp for cyanogenetic substances gave negative results. A positive test was obtained on seeds separated from the unground sample, but the quantity of hydrocyanic acid in the dried pulp as a whole would be negligible. Apple pectin pulp is subjected to thorough cooking in the process of producing pectin, sufficient not only to render it safe in the matter of cyanogenesis, but to sterilize the product as well.

## FEEDING VALUE OF APPLE BY-PRODUCTS.

### APPLE POMACE.

As early as 1888, Wolff (*143*) published data on the digestible nutrients contained in apple pomace. The list of materials for which he determined coefficients of digestibility, however, does not include apple pomace. Probably, therefore, the data he gives were secured by using the coefficients for some similar material, not by actual digestion experiments with apple pomace. The same is true for the data that he published in 1895, for which different coefficients were used.

Thus Lindsey, assisted by Holland and Smith, in 1903, probably was the first investigator to ascertain the percentage digestibility of nutrients in apple pomace (*100, 101*). His digestion experiments, which extended over two seasons, included complete trials with six sheep (full-grown, grade Southdown wethers). During the same periods productivity tests, in which apple pomace was compared with corn silage, were conducted with dairy cows. From 15 to 30 pounds of pomace were given daily to each cow. The pomace used was obtained fresh from a cider mill and was stored under cover. Juice gradually drained from the pile, but the material remained in

[28] It is not uncommon to find the total titrable acid in an 80 per cent alcohol extract higher than in the corresponding water extract, but to find an acid more highly ionized in the alcohol than in water is surprising.

[29] The presence in sugar beets of several relatively "strong" organic acids, including malonic, aconitic, and l-tartaric acids, has been reported by Rümpler (*126*). Of these, malonic has the highest ionization, with a reported "*Ka*" of $1.63\times10^{-3}$, at 25° C. If it be assumed that the acidity of the beet pulp extracts is due to a dibasic acid, such as malonic, instead of a monobasic acid, the values for *Ka* would be halved, giving 2.5 and 1.9 times $10^{-3}$ for the alcoholic and aqueous extracts, respectively, values not greatly exceeding that for the *Ka* of malonic acid. The higher observed values might be accounted for by the effect exerted by other dissolved constituents, such as salts.

good condition. A summary of the data obtained from these experiments is included in Table 11.

TABLE 11.—*Coefficients of digestibility of apple by-products (from the literature).*[1]

| By-product. | Portion of constituent digested.[2] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Dry matter. | Ether extract. | Crude fiber. | Protein. | Ash. | Nitrogen-free extract. | Galactans. | Pentosans. |
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Apple pomace fed to sheep[3] | 72 | 46 | 65.0 | | 49 | 85 | | |
| Dent corn silage fed to sheep[3] | 64 | 85 | 62.0 | 52 | | 69 | | |
| Flint corn silage fed to sheep[3] | 75 | 82 | 77.0 | 65 | | 79 | | |
| Apple pomace presumably fed to ruminants[4] | | 60 | 40.0 | 50 | | 70 | | |
| Dried apple pomace presumably fed to horses[5] | | 50 | 6.3 | 40 | | 70 | | |
| Fresh apple pomace presumably fed to horses[5] | | 43 | 6.7 | 44 | | 70 | | |
| Insoluble marc fed to man[6] | | | | | | | 76.8 | 88.7 |

[1] The net energy value of apples containing 81.8 per cent moisture is 0.1592 therm per pound. In computing this value from the digestible organic matter, Armsby (Pa. Agr. Exp. Sta. Bull. 142) used the factor 0.539 for the number of therms of energy lost as heat per pound of dry matter ingested. This factor is very close to that for wheat bran.

[2] The percentage of digestible constituent is determined by multiplying the percentage of the constituent by the coefficient (per cent digestible).

[3] Coefficients reported by Lindsey, Holland, and Smith (*101*); the results on corn silage are included for the sake of comparison.

[4] Coefficients calculated from Wolff's tables (*144*).

[5] Coefficients calculated from Kellner's tables (*94*).

[6] Coefficients reported by Schneider (*127*).

Lindsey and his associates found that the sheep did not digest the pomace evenly, although no digestive disturbances were observed. It was readily eaten, however. They ultimately concluded that (1) the total dry matter in apple pomace is about as digestible as that in the best grades of corn silage; (2) judged by composition and digestibility, pound for pound, apple pomace should approach average corn silage in feeding value; (3) judging from an 8-week alternate feeding trial with 2 cows, from 4 to 5 pounds of pomace is equivalent to 1 pound of "good cow hay"; (4) as much as 30 pounds of pomace per head may be fed daily with hay as roughage for mature cows and steers. They, however, advise feeding not more than 10 pounds at first.

In 1905 Kellner (*94*) published figures for the digestible nutrients in "fresh" and "dried" apple pomace which must have been based on coefficients entirely different from those of either Wolff or Lindsey. Here again apple pomace is not in the table which gives digestion coefficients based on actual trials, so that it must be assumed that coefficients for some material similar to pomace were used. Coefficients calculated from Wolff's and Kellner's data are given in Table 11. Evidently, from his extremely low coefficients for crude fiber, Kellner's results are based on experiments with animals other than ruminants, probably horses. It is possible that the digestion coefficients for apple by-products[30] reported by Lindsey and his co-

[30] Schneider (*127*) reported coefficients for the digestibility of the pentosans and galactans in apple marc, the pulp of the apple remaining insoluble after thorough extraction with cold water. The results of his experiments, which were conducted on human subjects, are reported in Table 11.

workers are the only ones which have been determined by actual digestion experiments.

Few tests showing the effect on milk production of feeding fresh apple pomace to cows have been reported. Most investigators have merely generalized on its comparative merits.

Johnson (*93*) stated that horses and colts ate frozen pomace with evident relish and benefit, but that cattle would have none of it.

Goessmann (*71*) quotes Wolff as stating that the "fodder constituents" in pomace are worth more than those in the same weight of turnips and as much as those in sugar beets.

Jenkins (*91*) fed pomace to horses and to cattle with good results. He states that it is prized as a food for these animals.

Houzeau (*87*) assigned a much lower feeding value to pomace, in comparing it with hay, than that reported later by Lindsey. In his estimation, 10 pounds of straight (one-pressing) pomace, or 7 pounds of exhausted "small cider" residue (after three pressings),[31] is equivalent to 1 pound of good hay. There is nothing in Houzeau's report, however, to indicate that his results were based on actual feeding trials. In fact, it is evident that he formed his opinion as to nutritive value on the content of crude protein. Furthermore, he dealt with pomace from French cider apples, which for generations have been grown with the view of obtaining a large yield of juice with a high content of tannins and sugars. Such pomace undoubtedly would contain less digestible matter than that from American sources, where, as a rule, good eating apples are used.

Houzeau, and earlier LeChartier (*97*), directed attention to the effect of the thoroughness of extraction of the juice upon the quality of the resulting pomace. Exhausting the marc by repressing, especially with the addition of water, lowers the content of soluble carbohydrates but increases the proportion of crude fat and protein.

European writers have assigned varying feed values to apple pomace. Desplanques (*90*) gives its nutritive value as half that of beets. He states that when fed to the extent of half the ration to cows it increases the milk flow. Warcollier and Hédiard (*140*) believe that it compares favorably with beet forage or with fresh beet pulp. Lhoste (*97*) states that approximately $3\frac{1}{3}$ pounds are equivalent to 1 pound of good hay, a comparison evidently based on Kellner's data.

In 1911 the Harleshausen Agricultural Experiment Station, Germany, compared apple pomace with maize (corn) meal as the basal ration for swine. The pomace proved to be the more economical when the supplementary feeds were potatoes, barley, wheat bran, and meat meal (*80*).

Most of the earlier writers, especially the French, discuss the popular beliefs prejudicial to apple pomace, either fresh or ensiled. Before the cause of contagious abortion in cattle was discovered it was generally believed that the feeding of apple pomace was a contributing factor. With more reason, perhaps, pomace was often blamed for off-flavor in milk or butter. Investigators now agree, however, that this is due to a fermented[32] or decomposed condition

[31] In France the press cake was broken up and reground with water between pressings.
[32] Normal silage fermentation is not injurious, but aerobic acidification appears to be so.

of the pomace. The opinion, at one time widespread, that the feeding of pomace or pomace silage to milch cows has a tendency to cause a shrinkage in milk flow has never received substantiation in any feeding trials conducted along scientific lines, although as much as 35 pounds of the silage per cow per day is commonly fed, and the feeding of from 45 to 50 pounds a day without ill effects has been reported. Investigators agree, however, that caution should be used in introducing pomace into the ration. The animals should become gradually accustomed to the new feed. French authorities insist that it should not constitute more than from one-fifth to one-half of the ration.

Some evidence exists that the ingestion of too large quantities of whole apples or of freshly pressed apple pomace may cause trouble. Marchadier and Goujon (*111*) state that more than 22 pounds of fresh pomace per day causes diarrhea in neat cattle. Hills (*84*) quotes his staff veterinarian as having frequently observed that after getting into orchards and eating heavily of apples cows "became sick, losing control of their limbs and appeared as if intoxicated." In many cases there was a serious shrinkage in milk flow and in other instances the animals dried up within 24 hours, even though in full flush of milk. Death ensued in some cases. On the other hand, Frear states (*68*): "Experience has shown that farm animals can be fed on rations containing a large proportion of apples, not only without injury to health, but with positive advantage." He adds that it has been found possible to avoid any injury from excess of free acid by sprinkling the pomace with chalk before feeding.

Strictly fresh pomace and whole apples may be classed together with respect to potential fermentation (content of fermentable carbohydrates). Grisdale, Robertson, and Bedford (*75*) fed refuse apples to dairy cows at the Canada Experimental Farms, 22 pounds per cow per day, with a slight increase in milk flow. There was a corresponding decrease in milk yield when the apples were not fed.

Strictly fresh moist apple pomace is rarely obtainable for any extensive period of time and then only by feeders near cider mills. Most so-called fresh apple pomace must have undergone some change of a fermentative character, so that in reality it is in the early stages of silage.

### APPLE-POMACE SILAGE.

No record of digestibility trials with ensiled apple pomace has been found. American investigators appear to have accepted for the silage Lindsey's digestion coefficients for apple pomace. Wolff's 1895 figures for the content of digestible nutrients in "fermented" pomace, "mashed" pomace, and dried pomace are derived from their percentage composition by the same coefficients as those for his "fresh" pomace, which evidently were not based on actual digestion experiments.

Several valuable feeding trials to determine the comparative milk production value of apple-pomace silage have been conducted. The most extensive were those carried out at the Vermont Agricultural Experiment Station from time to time between 1888 and 1903. In the five trials 27 cows were fed the silage. The results, summarized

by Cooke in 1889 (*59*) and by Hills in 1902 (*84*) and in 1903 (*85*), were as follows:

(1) The apple-pomace silage was well liked by the animals; (2) no undesirable effects followed its use, and the cows maintained their milk flow, although as much as 35 pounds per head daily was fed continuously in some cases; (3) pound for pound, apple-pomace silage approached corn silage in feeding value; (4) from the same quantity to 7 per cent more milk and butter was obtained per unit of dry matter than when corn silage was fed; (5) it was estimated that apple-pomace silage was worth from 75 to 100 per cent as much as good corn silage.

The Secretary of the Massachusetts Board of Agriculture (*113*) reported a discussion on pomace silage at a meeting of stock raisers. The opinion appeared to prevail that from 12 to 30 pounds once a day could well be fed, but that the silage affected the odor and taste of the milk when fed just before milking.

Shutt, of the Canada Experimental Farms (*128*), indorses the use of apple-pomace silage as part of the ration for dairy cows. When it constituted part of the food of four cows, the milk flow was maintained. Occasionally it was omitted, with a subsequent decrease of milk at the next milking.

Apple-pomace silage has been fed to swine with conflicting results. Goessmann (*72*), in experimenting with the production of the silage, packed pomace tightly into a cask, the inside surface of which had been coated with black tar varnish, covered it with tar paper and a layer of sand several inches thick, and weighted down the mass with heavy stones. The improvised silo was filled in October and opened the following May. By taking these precautions to exclude air, a pomace silage was obtained which had a degree of acidity of only 186, corresponding to a total acidity but little more than half that of average corn silage. Goessmann states that it was highly relished by cows and swine and " is equal to, if not superior to the apple pomace from which it was made."

On the other hand, a trial of apple-pomace silage as food for pigs resulted unsatisfactorily at the Illinois station. Morrow (*116*) reports that it was not relished by the pigs, and but very little was eaten. He remarks that the silage evidently was exceptionally acid, judging by its high content of ether extract. Unfortunately, no direct determination of the degree of acidity was made.

Because of their high water content neither the fresh pomace nor apple-pomace silage can attain great importance as a commercial feeding stuff in the undried condition.

## DRIED APPLE POMACE.

### Previous Investigations.

Comparatively little on the feeding value of dried apple pomace has been published.

In 1886 Frear (*68*) concluded, from an examination of a sample of dried pomace submitted by a correspondent, that this product ought to be " a valuable source of carbonaceous food, to be fed with a generous admixture of nitrogenous foods." Wolff and Kellner reported the content of the digestible nutrients, which, however, was evidently based on coefficients determined on some material similar to pomace, not on the pomace itself.

In 1918 Warcollier and Hédiard (*140*) and Lhoste (*99*) published data on the digestible nutrients in dried apple pomace. In neither case, however, is there any indication that actual digestion trials were conducted. The coefficients, calculated from the data, are identical with those used by Kellner (*94*).

Warcollier (*138*), who studied the use of dried pomace as a feed for army horses, advocated the substitution of a mixture of 70 per cent of dried pomace and 30 per cent of molasses for a part of the oats and bran in their rations, thereby making possible a saving of from 0.60 to 0.75 franc per horse per day. Such a mixture had a moisture content of 12 per cent. A later study, made in collaboration with Hédiard, included the whole problem of utilizing cider residues. Their report includes analyses of samples of pomace dried by "direct heat" and a calculation of the digestible nutrients. They state that desiccation is the best method of preserving cider residues, and that the dried pomace is very well liked by farm animals. They conclude that feeding experiments have shown that dried apple pomace can be included successfully in the ration of horses, but that no more than 2.2 pounds of the better grade of hay or 1.4 pounds of oats should be replaced by this material. Lhoste's data are taken entirely from Kellner's tables. He advises cooking the dried pomace before mixing it with other feeds.

There is little direct evidence on the effect of desiccation upon the feeding value of apple pomace. Maercker and Morgan (*29*) and Baeck (*20*) indicated that drying increased the food value of beet pulp. Blin (*47*) stated that stock, at times, prefer dried to fresh vegetable products. On the other hand, Warcollier (*137*) is authority for the statement that the drying of apples causes a striking change in composition, the percentage of insoluble matter being thereby increased from 24.2 to 82.1, on a dry basis. Where pomace is dried at moderate temperatures,[33] however, as is the general rule in America, it is believed that the food value is not impaired.

### Feeding Test.[34]

The primary object of the milk-production trial was to test the truth of the theory that dried apple pomace causes a decrease in the milk flow of the cows to which it is fed. This work also made possible a comparison of the milk production from a cow receiving dried apple pomace with that when the cow was given corn silage.

The greatest usefulness of apple pomace for dairy animals lies in the fact that it is a source of succulence in winter feeding. For that reason the dried apple pomace[35] was fed wet throughout the test. The material, which had been ground to a meal, was prepared by adding to it three times its weight of water several hours before it was fed.[36]

Only one cow was used in the test and the total quantity of dried pomace fed was less than 400 pounds. Therefore, the results obtained, while indicative, can not be accepted as conclusive.

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[33] In the rotary steam dryer, the temperature is said to vary from 75° to 135° C., while in the slatted-floor type of apple kiln the range is somewhat lower.

[34] Conducted by T. E. Woodward, Dairy Husbandman in Charge of the Beltsville Experiment Farm, Dairy Division, Bureau of Animal Industry, United States Department of Agriculture.

[35] Sample No. 37254—400 pounds dried and ground.

[36] It is now believed that the period of soaking should be shortened, particularly in warm weather, to an hour or two.

For a period of 30 days the animal, a pure-bred Holstein, received corn silage as the succulent portion of her balanced ration, which included grain and hay. The silage was then replaced by the apple pomace for 30 days, allowing a 10-day transition period for the change in diet. Allowance was made for another transition period of 10 days at the end of the apple pomace period, when the corn silage ration was resumed. The corn silage was continued for the third period of 30 days. Thirty-six pounds of soaked pomace (9 pounds of dried pomace to 27 pounds of water) was fed per day and an attempt was made to supply corn silage in such quantities during the third period that the average for the two silage periods would furnish approximately the same quantity of dry matter as that given in the pomace during the second period. The quantity of grain fed was constant throughout the experiment, and that of the hay was practically so. Table 12 summarizes the data from the feeding trial.

TABLE 12.—*Comparison of yield of milk from cow fed on dried apple pomace with that from cow fed on corn silage.*

| Feeding period No.[1] | Feed consumed. | | | | Yield. | | |
|---|---|---|---|---|---|---|---|
| | Corn silage. | Apple pomace (moistened). | Grain. | Hay. | Milk. | Butterfat. | |
| | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Per cent.* |
| 1 | 940 | | 252 | 245.0 | 558.2 | 22.33 | 4.00 |
| 3 | 900 | | 252 | 240.0 | 502.1 | 20.00 | 3.98 |
| Average | 920 | | 252 | 242.5 | 530.1 | 21.16 | 3.99 |
| 2 | | 1,080 | 252 | 240.0 | [2] 546.6 | [3] 21.68 | 3.96 |

[1] Feeding period, 30 days.
[2] An increase of 3.11 per cent when the pomace was fed.
[3] An increase of 2.45 per cent when the pomace was fed.

The cow received the same quantity of grain, $2\frac{1}{2}$ pounds less hay, and 160 pounds more wet pomace than corn silage during the pomace period as compared with the silage periods. On the same basis she produced $16\frac{1}{2}$ pounds (or 3.11 per cent) more milk and slightly more than one-half pound (or 2.45 per cent) more butterfat. This is equivalent to an increase of slightly more than one-half pound of milk and one-fourth ounce more fat per day, during which time $5\frac{1}{3}$ pounds more succulence, but presumably no more dry matter, was fed.

The pomace seemed to have no effect on the proportion of fat in the milk. It was always eaten with relish and no bad effects on the animal's system were apparent. The fact that the cow produced slightly more milk when given pomace than when given corn silage shows that the feeding of dried apple pomace had no untoward effect on the milk flow of this animal.

While there was a gradual increase in the milk flow during the first 30-day period, the decrease during the second and third periods was exactly the same.

Although the data obtained are perhaps not sufficiently extensive to warrant the drawing of definite conclusions, the indications are that no bad effects follow the feeding of dried apple pomace. It caused no decrease in the milk flow or in the yield of butterfat.

The pomace is a palatable feed and when fed as described it appeared to be equal, pound for pound of dry matter, to good corn silage as succulent food for the dairy cow. Owing to the property possessed by dried apple pomace of absorbing large quantities of water and swelling, it should never be fed dry, but should be allowed to soak in water for an hour or so before being fed.

The feeding of large quantities of dried pomace or of quantities containing excessive amounts of apple seeds might prove injurious.

## DRIED APPLE-PECTIN PULP.

### Previous Investigations.

In 1909 Shutt (*129*) made the following statement concerning moist apple-pectin pulp, samples of which he analyzed: "We should not consider that the nutritive value of this material was equal to that of the ordinary farm roots or of corn ensilage, but no doubt it could be used to advantage, if sound, to furnish a part of the succulent ration of the milch cow." This material contained 85 per cent of water. The manufacturer of the product made the following report: "We waited until our stock of roots (turnips and carrots) was finished and then used the pulp. We were pleased to find the milk did not decrease at all. Two small pigs used to eat all they could find and seemed to thrive on it."

Warcollier (*138*) mentioned that the press residues, after cooking apple pomace with water and repressing, were utilized for the feeding of stock. Arnou (*38*) suggested that the dried pectin residues be mixed with molasses for stock feeding.

### Preliminary Feeding Trial.[37]

A preliminary feeding trial was made to determine the palatability of the dried apple-pectin pulp, its effect upon the health of stock, the approximate quantity that should be fed, and the manner of preparing it. In this preliminary trial it also was possible to make a comparison with corn silage as to relative milk production value. As dried pectin pulp should prove of greatest value as a source of succulence for dairy cattle in the winter, it was fed wet throughout both experiments. The dried pulp which had been ground to a meal was prepared by adding to it three times its weight of water, several hours before feeding.[38]

In order to determine the palatability and to find out whether there were any detrimental effects on the animal body, the moistened pulp[39] was fed to four cows for five days. The first day a part of the corn silage[40] included in their ration was replaced by the pulp; then the silage was entirely replaced by a relatively greater quantity of pulp.

In the comparative milk production test, the aim was to supply the same quantity of dry matter in the pectin pulp as the cow received in the form of corn silage. A young Holstein in lactation was chosen, and the comparison between the moistened pectin pulp

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[37] All following feeding trials were conducted by T. E. Woodward, Dairy Husbandman in charge of the Beltsville Experiment Farm, Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture.

[38] In warm weather the pulp should not be soaked for more than two hours.

[39] Sample 36675—400 pounds of dried and ground pulp.

[40] Same lot of silage as samples 36873 and 37157.

and silage was made by the "reversal" feeding method, as in the experiment with apple pomace, except that in this pectin pulp trial the test periods were 20 days, with 5-day transition intervals. The quantity of grain and soy bean hay fed was kept constant throughout the trial. Table 13 summarizes the data obtained in this feeding trial.

TABLE 13.—*Comparison of yield of milk from cow fed on dried apple-pectin pulp with that from cow fed on corn silage.*

| Feeding period No.[1] | Feed consumed. | | | | Yield. | |
|---|---|---|---|---|---|---|
| | Corn silage. | Pectin pulp (moistened). | Grain. | Soy-bean hay. | Milk. | Butter-fat. |
| | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* |
| 1 | 560 | | 140 | 200 | 311.5 | 14.32 |
| 3 | 640 | | 140 | 200 | 312.6 | 14.99 |
| Average | 600 | | 140 | 200 | 312.0 | 14.65 |
| 2 | | 726 | 140 | 200 | [2] 356.9 | [3] 15.69 |

[1] Feeding period, 20 days.
[2] An increase of 14.4 per cent when the pectin pulp was fed.
[3] An increase of 7.1 per cent when the pectin pulp was fed.

The pectin pulp seemed to be of average palatability, and no bad effect on the health of the cows was noted. In the short palatability test, one cow received 58 pounds of the moistened pulp, equivalent to 14½ pounds of the dried material, in a single day.

An unusual increase in milk yield occurred during the period when pectin pulp was fed, but this could not be considered conclusive as the test was conducted on one cow only and for a relatively short time.

### MILK PRODUCTION TRIAL.

Dried pectin pulp has about the same proximate composition and ability to absorb readily two or three times its weight of water as dried beet pulp. For this reason beet pulp was selected for comparison in the principal production test.

The feeding trial, conducted by the double reversal method, was started late in April.[41] Six Holstein cows, three pure bred and three grade, were divided into two groups. One group received soaked beet pulp; the other was fed the soaked pectin pulp as the succulent portion of the diet. Ten days were allowed for the cows to become accustomed to their rations, and data were then taken for a period of 30 days. At the end of this time the rations were reversed, and after a 10-day transition interval, data were recorded for another period of 30 days.

Both the pectin and beet pulps were prepared by moistening them with three times as much water, by weight, and they were allowed to stand (soak) from one feeding period to the next. Forty pounds of wet pulp per day was offered to each cow in both groups. The remainder of the daily ration consisted of about 10 pounds of alfalfa

[41] The time of year is mentioned because of the effect that the hot weather is believed to have exerted on the appetite of the animals for the novel feedstuff.

hay per animal and a quantity of mixed concentrates,[42] depending on the yield of butterfat. The concentrates were fed at the rate of 10 pounds per pound of butterfat produced. The milk was weighed at each milking, and for 2 or 3 days near the middle of each 10-day period samples were taken from each cow for fat testing. The butterfat production results thus obtained were used in determining the quantity of concentrate mixture to be fed the following 10 days. A more accurate comparison of the relative milk production values of the two feeds might have been possible had the animals' weights been more closely controlled. A summary of the experimental data is given in Table 14. The apparent discrepancy between the figures for quantity of concentrates fed and those for butterfat multiplied by 10 is accounted for by the fact that the butterfat yield decreased consistently for both groups of cows, so that while the animals were receiving quantities of food based on a certain fat yield, they were actually producing less butterfat.

TABLE 14.—*Comparison of yield of milk from 6 cows fed on dried apple-pectin pulp with that from 6 cows fed on dried beet pulp.*[1]

| Feed consumed.[2] | | | | | | | | Yield.[2] | | | | Changes in body weight.[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mixed concentrates. | | Alfalfa hay. | | Beet pulp (moistened). | | Pectin pulp (moistened). | | Milk. | | Butterfat. | | |
| Total. | Per pound of butterfat. | Total. | Per pound of butterfat. | Total. | Per pound of butterfat. | Total. | Per pound of butterfat. | Total. | Per pound of butterfat. | | | |
| *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Pounds.* | *P. ct.* | *Lbs.* |
| 1,839.2 | 10.7 | 1,800 | 10.5 | 7,200 | 41.9 | ....... | ....... | 4,976.5 | 28.96 | 171.86 | 3.453 | +109 |
| 1,627.6 | 10.6 | 1,785 | 11.7 | ....... | ....... | 6,759 | 44.2 | 4,375.7 | 28.60 | 152.93 | 3.495 | − 67 |

[1] Feeding period, 30 days.
[2] These figures represent the total feed consumed and yields by the animals in both groups while receiving the two pulps, respectively; hence they are the totals for 6 cows for 30 days.
[3] Total.

The results of this trial were less favorable to the pectin pulp than those in the preliminary test where corn silage was used. Its relative palatability appeared to be lower, as three of the six cows refused part or all of it at one time or another during the experiment. At no time was the beet pulp refused by any of the cows. Even if only the data for the three cows that ate the pectin pulp at all times be taken, the milk yield is favorable to the beet pulp, 2,678.8 pounds of milk being produced on the pectin pulp ration and 2,804.7 pounds on beet pulp. The data for all six animals show that when on apple-pectin pulp, the cows ate less succulence, produced less, and lost in weight, whereas while on beet pulp there was a gain in total weight.[43] For each pound of butterfat produced more food was consumed while on the pectin pulp ration.

[42] The concentrate mixture was composed of corn meal, 100 pounds; ground oats, 100 pounds; wheat bran, 100 pounds; linseed meal, 50 pounds; and cottonseed meal, 50 pounds.

[43] At the beginning of the principal test against beet pulp, one cow of the first pair started showed a remarkable increase in milk production for the 10-day transition period over the previous 10 days. This pair of animals had been receiving a ration in which corn silage constituted the succulence and the gain was made on changing to the pectin pulp. The other cow of this pair showed a much less pronounced decrease and just previously her concentrate allowance had been cut one-third.

How can the apparently conflicting results of the two trials of apple-pectin pulp be reconciled? If, in general, beet pulp tends to produce more milk than corn silage per pound of dry matter fed, it follows that the pectin pulp would make a better showing against the corn silage. The total available records[44] of feeding experiments directly or indirectly bearing on the relative production values of the dry matter in corn silage and beet pulp favor the beet pulp. Furthermore, for every pound of pectin pulp actually consumed in the tests, more beet pulp dry matter than corn silage dry matter was eaten. Also the earlier trial, using corn silage, was conducted in midwinter, while the test using beet pulp was made in late spring and summer. Any falling off in appetite during hot weather of cattle accustomed to such liberal feeding as were the cows used in these tests would be likely to manifest itself in a refusal to clean up the less familiar feed. At higher temperatures the long soaking[45] to which the pulp was subjected preparatory to being fed might injuriously affect its palatability and wholesomeness. A palatability test made the latter part of September, while not taking account of daily temperature, showed a gradual lessening of palatability of wet pectin pulp on standing. The season then at which the trial was made may have had an effect on the relative yields, as it is generally understood that, other factors being equal, lowered palatability is reflected in lower returns.

Dried apple-pectin pulp should prove of value as feed for the dairy cow. It may be classed as a bulky, carbonaceous semiconcentrate, high in crude fiber, similar to dried beet pulp. Because dried pectin pulp has the property of absorbing large quantities of water and swelling, when fed liberally it should be well moistened with water an hour or so before feeding.

Pound for pound of dry matter fed, it seemed to be superior to good corn silage, perhaps intermediate between that and beet pulp as a succulent feed for cows in lactation. Its superior showing over corn silage, however, cannot be accepted as conclusive.

The palatability of pectin pulp appeared to vary. Certain of the cows under test in the hot weather refused the soaked pulp. However, the loss of appetite for the pectin pulp may in part be attributed to the fact that it was an unfamiliar feed.[46] Dried apple-pectin pulp absorbs molasses readily, and becomes more palatable by its addition. As the vehicle in a molasses feed, it should prove as satisfactory as dried pomace is reported by foreign investigators to be.

While it is probable that the extraction with boiling water to which the apple-pectin pulp is subjected during its process of manufacture and the subsequent heating during drying removes the hydrocyanic acid, any apple product which contains an excessively large quantity of seeds should be fed with caution.

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[44] References in the literature cited on which this statement is based are *21, 29, 32,* and *33*.

[45] Soaking from one feeding until the next involves subjecting the feed over night to conditions which in hot weather might be conducive to fermentations capable of affecting the quality of the "mash."

[46] Much the same difficulties were encountered when dried beet pulp was being introduced as a feeding stuff (*22, 23*).

### COMPARATIVE COST OF FEEDING APPLE BY-PRODUCTS.

The selling price of dried beet pulp in March, 1922, averaged $30 a ton in carload lots. In the feeding experiments here reported dried apple pomace and dried pectin pulp were also compared with corn silage. From 3.4 to 3.3 pounds of silage was fed per pound of dried pomace or pulp. Hence, if the selling price of dried pomace or pulp were $25 per ton, the cost per ton of silage would need to be from $7.35 to $7.58, in order that the costs of the two rations would be equal.

According to the Bureau of Agricultural Economics, the cost of producing a ton of silage from the 1921 corn crop varied between $5.32 and $6.77 for Illinois, Indiana, Iowa, Missouri, and Nebraska. Therefore in the experiments herein reported the silage ration would have been the cheapest if the dried apple products cost $25 per ton.

### SUMMARY.

In spite of the excellent work done by the State experiment stations and many individual investigators in establishing the value of sound apple pomace and apple-pomace silage as cattle food and showing the extravagance of allowing such material to be wasted, thousands of tons of apple pomace are still lost because of indifference on the part of stock raisers or the lack of facilities for preserving it.

Only a small part of the 150,000 tons of moist apple pomace annually produced by commercial cider and vinegar makers in the United States can be profitably used in the fresh condition. It may be ensiled, when it yields a succulent cattle food comparable with corn silage, of special value in the winter feeding of stock. The quantity that can be utilized in this way, however, is limited because of the relatively high cost of transportation for material having such a high water content.

The profitable utilization of apple pomace, therefore, depends upon its preservation by dehydration. The necessity for producing new and cheap feeding stuffs and the advance made in improving large-capacity drying apparatus make dried apple pomace worthy of consideration as a promising commercial food for stock.

Experiments in France during the World War showed that a mixture of 70 per cent of dried pomace and 30 per cent of molasses, by weight, could be substituted advantageously for a part of the oats and bran in the rations of the army horse. The Department of Agriculture has shown that dried apple pomace is a semiconcentrated feeding stuff, of medium protein and ether-extract content, capable of absorbing relatively large quantities of water or molasses. Some of the ether extract represents wax-like substances dissolved from the skins, and these can not be considered digestible fats.

A study of the specific acidity of dried apple pomace indicated that if the effect is principally due to the presence of malic acid, its ionization has been decidedly depressed.

Apple seeds separated from the dried pomace contain a cyanophoric compound, reported as amygdalin, which yields hydrocyanic acid

when digested with emulsin. No hydrocyanic acid was detected when the product was digested with water alone, an indication that the enzyme was destroyed during the process of preparing this commercial sample.

In the feeding tests conducted in the department the animals ate the dried apple pomace with evident relish and suffered no ill effects from it. Pound for pound of dry matter consumed, the moistened apple pomace seemed to be slightly more efficient as a milk producer than good corn silage.

Dried apple-pectin pulp, the residue of apple material from which a large part of the pectin and other substances rendered soluble by treatment with boiling water, as well as substances extracted by cold water, have been removed, is a semiconcentrated feed of the same type as dried apple pomace and dried beet pulp. As a rule, it contains more crude protein and ether extract and less available carbohydrates than dried apple pomace. Because of the thorough cooking to which it is subjected, pectin pulp is believed to be a safe food for stock, in spite of the fact that the apple-seed tissues present in the pulp contain amygdalin.

The total acidity of the dried pectin pulp was slightly higher than that of the dried pomace, while the "strength" of its acid-reacting substances was somewhat lower. On the other hand, the dried beet pulp used in one of the feeding experiments had high acid ionization values. While the total titrable acidity of extracts of the beet pulp was relatively low, the ionization of the acid appeared to be over 30 per cent in an 80 per cent alcohol solution and 7.5 per cent in a water extract.

Pound for pound of dry matter, pectin pulp seemed to be intermediate between good corn silage and beet pulp as a succulent feed for cows in lactation.

The palatability of the dried apple-pectin pulp varied decidedly at different times and with different cows. The addition of molasses, for which it is a good absorbent, increases its palatability.

The work here reported indicates (1) that the valuable extractives of apple pomace, such as sugars and pectins, should be utilized in the preparation of jelly stock, prepared pectin, or other human foodstuffs, and all surplus apple pomace dehydrated at a moderate temperature; and (2) that all surplus dried pomace and other suitable apple residues, such as pectin pulp, should be utilized as stock food.

All seeds should be either separated from the apple pomace which is to be used directly as a feeding stuff, to obviate any danger to the stock from hydrocyanic acid, or, if this be impracticable, the pomace should be thoroughly heated to destroy the emulsin contained in the seeds.

The seeds might serve as an additional source of profit by sale to nurserymen or by distilling the volatile oil from them.

The dried apple pomace and pectin pulp should be moistened before being fed because of their capacity to absorb large quantities of water.

Concentrates high in protein content should be included in the rations in which apple pomace or apple-pectin pulp supplies the succulence.

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